SUPERCRITICAL UV: A NEW DISINFECTION TECHNOLOGY FOR HARD TO TREAT LIQUIDS

Dr. Matthew Sells (NovoLabs), Prof. Andrew Shilton (Massey University)

ABSTRACT (500 WORDS MAXIMUM)

Ultraviolet disinfection is commonly used in wastewater applications as the final step before discharge to the receiving environment. Traditional systems typically require the water to be of a relatively high clarity for disinfection. This clarity is referred to as UV transmittance where 100% is clear water. Typical ‘submerged bulb systems’ generally require a UV transmittance (UVT) of at least 60% to provide adequate disinfection although lower e.g. 40% is possible with some designs. However, to achieve a UVT of even 40% in wastewater can be challenging for industrial effluents, or where municipal systems contain a high amount of trade waste thereby requiring additional costly upfront treatment, such as chemical dosing.

UV light is absorbed very quickly in liquids. According to the Beer-Lambert law, this decrease in UV light intensity is exponentially related to the depth of the liquid, meaning the thicker the liquid depth the lower the UV light intensity. This loss of effective UV light intensity becomes highly pronounced in low UVT liquids.

Massey Universities new start-up NovoLabs Limited has a novel (patent pending) technology for achieving UV disinfection of liquids with UVT well below 40%. This approach is called Supercritical UV disinfection. The device triggers a very thin but very fast-moving flow of liquid in an open channel – this flow pattern is called supercritical flow. The liquid is only a few mm in depth which ensures high intensity UV light penetration throughout, however the high velocity of the supercritical flow still allows a high flow throughput to be achieved. Instead of having the bulbs submerged in the channel, the bulbs irradiate the UV light down into the liquid from above the treatment channel.

Case study: The Manawatu District Council spends hundreds of thousands of dollars a year for chemicals to improve the UVT of their effluent so their traditional UV system can meet their < 1,000 MPN/100mL E. coli consent for land irrigation. NovoLabs supercritical UV device consistently achieved an E. coli concentration below 1,000 MPN/100mL (consent requirement) without any chemical treatment required. This could potentially save the rate payers $1,000 per day in operating costs.

KEYWORDS

Ultraviolet, disinfection, wastewater

PRESENTER PROFILE

Dr Matthew Sells completed his PhD on wastewater treatment back in 2019. He has since been working on research projects in the wastewater area at Massey University. Recently he has been part of the team working with Prof Andrew Shilton to take the patent pending supercritical UV technology out into commercial use in industry.

1 INTRODUCTION

Disinfection is becoming an increasingly common requirement for wastewaters before discharge to the receiving environment. As regulations for disinfection become increasingly common, treatment plants are facing costly upgrades to meet these new consents. Disinfection options to meet these new consents include chlorine-based chemicals, ozone, and ultraviolet light. While chlorine and ozone can provide disinfection of wastewater, one of their big disadvantages is they are non-specific and react with the organic material in the water. This means if a wastewater contains high organic material, like a lot of industrial wastewaters or primary domestic wastewater, a large amount of the chlorine or ozone reacts with the organic material before the required disinfection is achieved. Furthermore, with chlorine-based treatments in particular, undesirable toxic by-products and potential carcinogens can be produced when reacting with the organic material (Park, et al., 2016; Richardson, et al., 2007).

UV disinfection is relatively low cost when compared to alternative treatments (Collivignarelli, et al., 2000); can provide high disinfection of bacteria and viruses; and is not known to react with the organic material to produce toxic by-products (Lazarova, et al., 1998). UV light is produced by special lamps that emit light within the UV spectrum. Typically, for the standard low-pressure UV lamps, this is UVc light predominantly at the germicidal wavelength of 254nm. A traditional UV system involves configuring these lamps in an array submerged within the liquid flow (Figure 1).

Figure 1: Traditional submerged bulb UV system

The effectiveness of UV systems often comes down to the clarity of the liquid. This clarity is referred to as the UV transmittance (UVT) which is effectively how much UVc light (254nm) can pass through 1cm of the liquid. A UVT of 100% is clear water allowing all the UVc light to pass through the liquid, where 0% is completely opaque to UVc light. Traditional submerged bulb systems typically require a UVT of >60%, or >40% if using much higher power input, to provide adequate disinfection. However, to achieve a UVT of even >40% can be challenging for industrial effluents, or where municipal systems contain a high amount of trade waste. Improving the UVT of these wastewaters to within the range where traditional UV systems are effective can be costly and add complexity to the treatment system. For example, the required upgrade could be coagulation/flocculation to reduce the suspended solids or an entire biological treatment system to reduce organic loading, which is an additional cost on top of the UV system.

The reason why the liquid needs to be of high clarity is that UVc light is absorbed very quickly in liquids. According to the Beer-Lambert law, this decrease in UV light intensity is exponentially related to the depth of the liquid, meaning the thicker the liquid depth the lower the UV light intensity remaining in the liquid at that point. This loss of effective UV light intensity becomes highly pronounced in low UVT liquids.

Massey Universities new start-up NovoLabs Limited has patent pending new technology for achieving UV disinfection of liquids with UVTs well below 40%. This approach is called Supercritical UV (SCUV) disinfection. The device triggers a very thin but very fast-moving flow of liquid in an open channel – this type of flow hydraulics has a Froude number of >1 and is known as supercritical flow. The liquid can be only a few mm in depth which ensures high intensity UV light penetration throughout, however the high velocity of the supercritical flow still allows a high flow throughput to be achieved. Instead of having the bulbs submerged in the channel, the bulbs irradiate the UV light down from above the treatment channel.

This paper presents a case study showing the effectiveness of supercritical UV disinfection in hard to treat, low UVT liquids.

2 CASE STUDY: MANAWATU DISTRICT COUNCIL

2.1 FEILDING TREATMENT PLANT

The Manawatu District Council (MDC) Feilding treatment plant is a domestic wastewater plant that contains a large amount of industrial effluent inputs. The average flowrate is 7,500 m^3/d. The current treatment process consists of: screening, anaerobic pond, aerobic lagoon system, settlement, chemical dosing with an actiflo system, followed by conventional submerged bulb UV.

The actiflo system is used to remove phosphorus and clean the water to improve the UVT before the traditional submerged bulb UV system. The UVT before the actiflo system when monitored for 1 month ranged from 12% up to 42% and averaged 28%. The actiflo chemical dosing system increased the UVT to greater than 60% which was required for the traditional UV system to be able to provide adequate disinfection.

MDC discharge to river for part of the year and irrigate for the remaining period to land. During river discharge there are strict consents for both nutrients and pathogens which requires both the actiflo chemical dosing and traditional submerged bulb UV system to be operating effectively. When irrigating to land the main consent target is for an *E. coli* concentration below 1,000 MPN/100mL. However, with the current setup, the actiflo system is required to run all year round to ensure the UVT is high enough for disinfection in the traditional submerged bulb system to occur.

2.2 TESTING SUPERCRITICAL UV AT FEILDING TREATMENT PLANT

The supercritical UV device was installed immediately before the actiflo system (i.e. no chemical dosing) and operated from the start of December to the end of January 2021. The average E. coli removal through the SCUV system is shown in Figure 2.

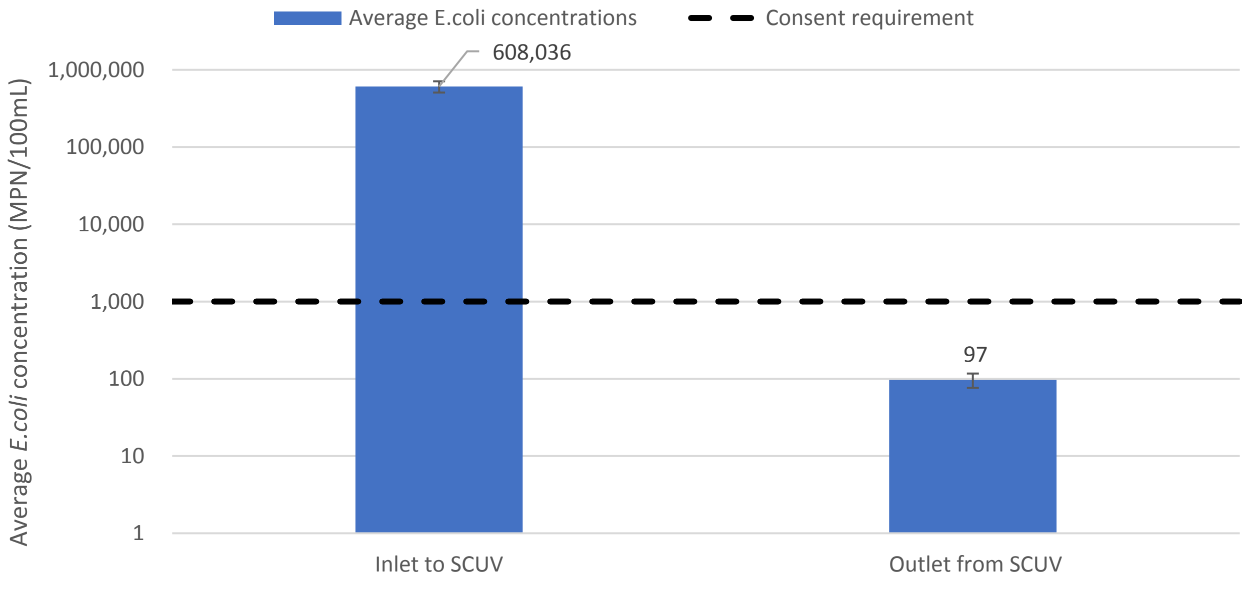

Figure 2: Average *E. coli* removal through the SCUV device. **UVT average of 28%**

The average *E. coli* concentration prior to supercritical UV disinfection was approximately 600,000 MPN/100mL. The UVT was 28% on average which is well below the UVT of 60% normally required for traditional submerged bulb UV treatment. As shown in Figure 2, the SCUV device successfully reduced the *E. coli* concentrations to below 100 MPN/100mL, well below the consent requirement of 1,000 MPN/100mL, without the need for any chemical dosing. This is a 3.8 log removal in wastewater with an average UVT of 28%.

The results shown in Figure 2 suggest that when MDC irrigates their wastewater, the supercritical UV device could be used to eliminate the need for the chemical dosing. This was estimated to potentially save in the order of $1,000/day in operating costs. Furthermore, with proper irrigation practices, this would allow the nutrients in the wastewater to be recycled instead of being locked into metal precipitates in a chemical sludge requiring disposal.

A second location was also briefly tested. This location was immediately after the anaerobic pond. The UVT in this location was extremely low at approximately 1.2%! The removal of *E. coli* through the SCUV device in a one-day test after the anaerobic pond, and, for comparison, immediately prior to the actiflo system on the same day, is shown in Figure 3.

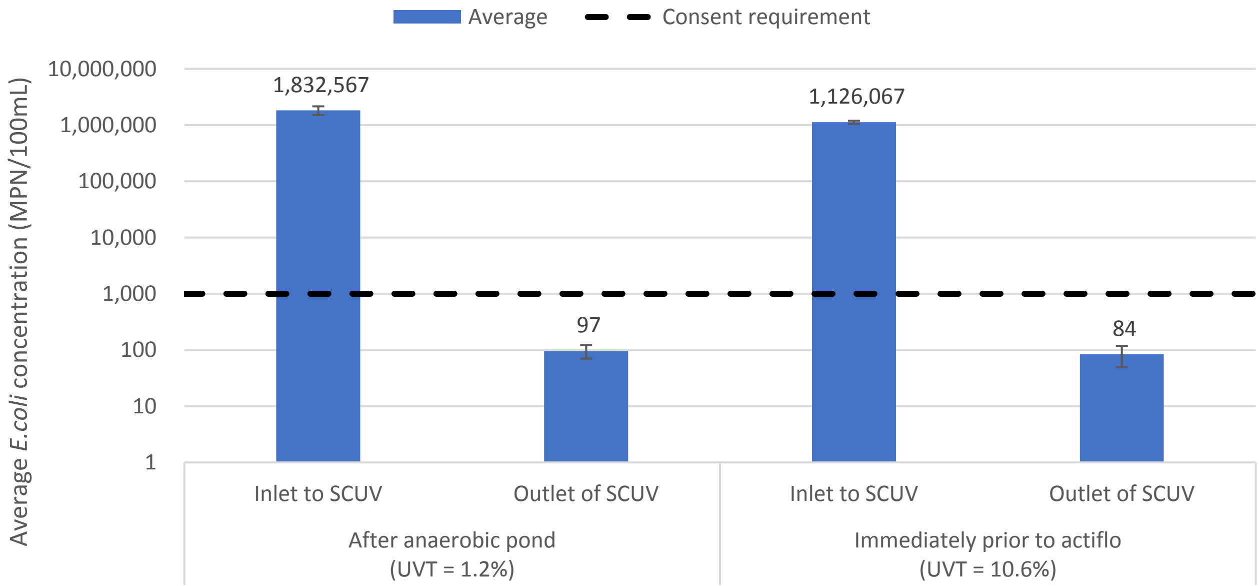

Figure 3: Average *E. coli* removal in a one-day test through SCUV device immediately after the anaerobic pond (Left) and, for comparison, immediately prior to actiflo (Right).

As shown in Figure 3, even at the extremely low UVT of 1.2% after the anaerobic pond, the SCUV device achieved excellent removal down to 97 MPN/100mL. This result was higher than the result obtained on the same day for the position immediately before the actiflo system, but, for a UVT of only 1.2%, over 4 log removal is remarkable.

These results show that UV treatment of extremely low UVT liquids can be possible with the novel supercritical UV.

3 CONCLUSIONS

Ultraviolet disinfection typically needs the water to be of a high clarity for effective removal of pathogens. Massey Universities new start-up NovoLabs Limited has a novel technology called supercritical UV which has been demonstrated to be able to provide effective reduction of *E. coli* in extremely low clarity wastewaters with UV transmittance down to 1.2%. Implementing supercritical UV at the Feilding treatment plant has the potential to save $1,000 per day in chemical costs alone.

ACKNOWLEDGEMENTS

The authors would like to thank and acknowledge Chris Pepper and the Manawatu District Council for their assistance with testing at the Feilding Treatment Plant.

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