USE OF UV/VIS SPECTROMETER FOR CONTROLLING A TERTIARY TREATMENT PROCESS

S. Kumarasingham* and H.I. Tan*

****Watercare Services Limited, Auckland, New Zealand***

(E-mail: s.kumarasingham@water.co.nz)

ABSTRACT

The use of online monitors for monitoring and control purposes has gained prominence in recent years. Watercare Services Limited operates the largest advanced wastewater treatment plant in New Zealand and has implemented the online instrument for controls purposes at Mangere Wastewater Treatment Plant (WWTP). An in-situ UV/VIS spectrometer was used to measure UV transmittance (UVT) in the UV inlet channel at Mangere WWTP. The measurement is use to control the UV plant dose system by determining a variable offset factor based on the UVT% measured. Addition of UVT% for dose calculation was derived due to the work undertaken by a comprehensive study undertaken by an expert Disinfection Review Group (DRG). The developed algorithm was first implemented to one of the twelve UV channels for testing and the results monitored prior to implementation on all UV channels. Variability in UVT% was monitored against another online UVT% instrument. Stringent maintenance and calibration of the spectrometer were introduced to ensure reliable measurements. The algorithm was rolled out to the other eleven channels once the performance was proven satisfactory by Watercare Services. This paper describes the process of developing and implementing the new dosage control to the UV plant.

KEYWORDS

UV/VIS spectrometry, in-situ, UV dose, UVT%, control

1 INTRODUCTION

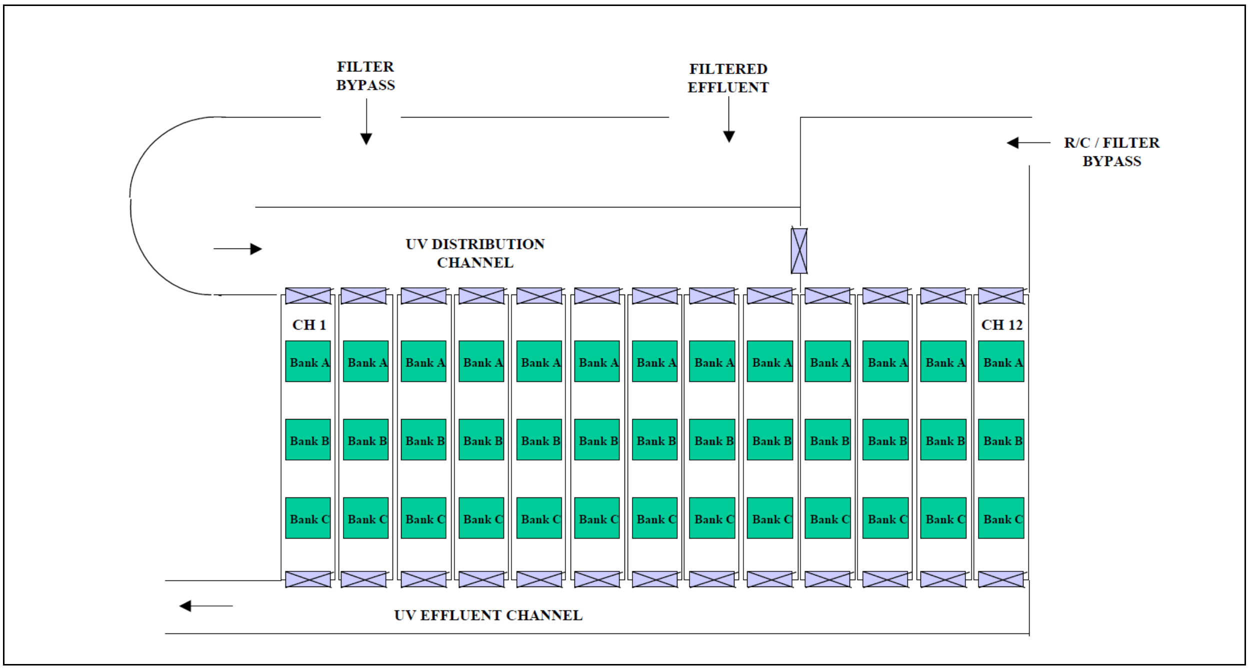
Mangere Wastewater Treatment Plant (WWTP) is the largest advanced wastewater treatment plant in New Zealand operated by Watercare Services Limited. The plant has been serving the greater Auckland region and has been upgraded several times since it was built in 1960. The latest major upgrade was completed in 2003. One of the key drivers was to ensure the quality of treated effluent being discharged into Auckland's Manukau Harbour and reduce any nuisance effects. The plant was upgraded from a waste stabilization pond system with fixed growth reactors to meet lower consent limits for nitrogen removal. The 500 hectares of oxidation ponds were replaced with advanced wastewater treatment processes, which included upgrades to the secondary and tertiary unit processes. Due to the upgrade the ponds were restored as well as 13 kilometers of shoreline was restored.

The unit processes on the liquid treatment include inlet screens, primary sedimentation, biological reactors-clarifiers, filters and UV disinfection. The plant has a design capacity to treat up to 16.5 m^3/sec. There is also a comprehensive solids stream which includes thickening unit processes for both primary and secondary sludge, anaerobic digesters, centrifuges and alkaline stabilization.

The plant was also one of the first in New Zealand to be granted a dose based consent. As part of the upgrade work was undertaken by leading specialist, DRG to determine the Reduction Equivalent Dose (RED), a process of verification of the applied dose (dose calculated from the Programmable Logic Controller, PLC). This study was done over a period of time and an algorithm was developed which took into account the need for UV transmittance to be used as a control variable.

The UV disinfection plant features 12 UV channels, each of which contains three banks of UV lamps. Therefore there are 36 banks of lamps in total. Each bank contains 12 modules of UV lamps. Each module is composed of 18 lamps. Thus the total number of lamps is 7776. The UV system consists of an automated wiping system to prevent build-up of media on the quartz sleeve and hence maintain UV transmission efficiency. Figure 1 shows the layout of the 12 UV channels (Watercare, 2010).

Figure 1: UV disinfection plant layout (Watercare, 2010).



The UV treatment process requires measurement of transmittance. The performance of UV plants can be limited by the quality of the influent transmittance. Measurement at Mangere of the UV transmittance is by one in-situ UV/VIS spectrometer and two online UV transmittance instruments. This paper describes the process of developing and implementing the new dosage control to the UV plant.

2 BACKGROUND

Definition of UV transmittance is the ability of a wastewater to transmit UV light, usually defined as the percent transmittance. Organic and inorganic compounds and suspended solid material can absorb or scatter UV light, which affects the percent transmittance. It has been noted that as transmittance of a wastewater decreases, the average UV intensity within the UV reactor decreases. (Darby et al., 1995)

As part of the upgrade a pilot study was conducted to recommend a disinfection process that would achieve a four log reduction in seeded viruses. An independent experts group was established, called the Disinfection Review Group (DRG) to recommend the best treatment option. The DRG recommended ultraviolet (UV) irradiation based on the pilot study.

2.1 UV PLANT CONTROL DESCRIPTION

The UV dose is calculated based from UV intensity within each bank of lamps and the amount of time within each channel. Intensity is measured continuously. The irradiation time is derived from a calculation based on measured changes in channel water level and changes in level across a rectangular weir. The values are measured online and a fifteen minute average UV dose is calculated. This is required for consent compliance at Mangere WWTP, which states a requirement of 35 mWs/cm^2 for at least 99% of the time in each operational channel.

At the Mangere WWTP UV transmittance (UVT) % is measured using online instruments. A primary spectrophotometer and a secondary unit is used to monitor the inlet UVT % of channel 1 to 8 while the second unit measures the inlet UVT% of channel 9 to 12.

The main system controller for the UV treatment plant incorporates a supervisory distributed controller system (DCS). Each of the UV channels has a dedicated programmable logic controller (PLC) to perform a variety of control and signal processing functions. A network connection with the PLC is used to communicate with the DCS.

The UV disinfection treatment dose control is to manage the minimum UV dose applied to each of the channels that are in operation. There are a few terms associated with UV dose. Table 1 shows the definition of each term.

Table 1: Mangere WWTP UV disinfection plant parameter definitions.

Parameter	**Definition**
Minimum Dose	The minimum UV dose that must be applied, in order that the plant design criteria is met. Set value of 35 mWs/cm^2
Offset Dose	"Safety factor" added to minimum dose. Input value of 25 mWs/cm^2 which can be change by operator
Target Dose	Setpoint value that is compared with applied dose to determine number of lamps in operation. Target Dose = Minimum dose + Offset dose
Bank Applied Dose	Product of intensity and retention time of bank Bank Applied Dose = Intensity × Bank Retention Time
Channel Applied Dose	Summation of applied UV dose from all banks Channel Applied Dose = Bank A Applied Dose + Bank B Applied Dose + Bank C Applied Dose
Assist Bank On and Off Dose	Product of target dose and a percentage set point Assist Bank On Dose = Target Dose × Percentage Set Point A Assist Bank Off Dose = Target Dose × Percentage Set Point B

In a channel, the control system determines the number of UV banks (2 or 3) required to be in operation as well as power output of the UV lamps (60 or 100%) to ensure that the applied dose is always higher than the minimum dose. The number of banks in operation is determined by comparing the applied dose against assist bank status, either being on or off based on dose. One bank is selected to switch on and off and is known as the assist bank. The bank will switch on if the applied dose is lower than the assist bank on dose and off if it's higher than the assist bank off dose. UV lamps will switch from 60 to 100% power output if there is a reactor and filter bypass and if the UVT is under 45% for 15 minutes.

The number of UV channels to be in operations is controlled base on the total flow rate and applied UV dose in each channel. The number of UV channels in operation increases and decreases as the total flow rises above or falls below pre-set switching thresholds. Extra UV channels will be brought into operation if the applied UV dose in any operating channels falls below the target UV dose.

2.2 DESCRIPTION OF FINAL ALGORITHM CHANGE

As mentioned in the introduction section, a recommendation was made by the Disinfection Review Group (DRG) to monitor dosage based on a reduced equivalent dose (RED). RED is dependent on the UV influent UVT%. As UVT% deteriorates, RED will also reduce. Therefore to ensure that compliance is met, another offset which varies with UVT% was introduced. This offset is labeled as UVT% offset dose. The formula for the adjusted target dose is as follows:

Adjusted Target Dose = Minimum Dose + Offset Dose + UVT% Offset Dose

The concept is that as UV influent quality worsens (decrease in UVT%), the UVT% offset dose value will increase. This increases the target dose hence triggering the operation of additional bank earlier. Table 2 shows the variation of offset doses with UVT%. The range of UVT% offset dose was set from 0 to 45 mWs/cm^2. The table is used as a lookup table to vary the offset.

Table 2: UVT% offset dose with corresponding UVT%.

UVT (%)	**UVT% Offset Dose (mWs/cm^2)**
65	0
64	2.14
63	4.28
62	6.42
Down to 45	45

3 METHODOLOGY

UV channel 2 was selected as the trial unit. The initial change was implemented in August 2011. The change involved manipulating the existing offset dose by varying the dose based on UVT%. The adjusted target dose mentioned in Section 2.2 was applied in December 2012. Couple of modifications was carried to further optimise the new algorithm. The changes are described in Section 4.1.

The data was analysed based on 15 minutes average time bands. RED values which have flow of less than 0.1 m^3/s and less than 45 UVT% were removed. The reason for that is because the channel is considered not operating when flow is less than 0.1 m^3/s. Values under 45 UVT% were also not considered because the UV channels operate at 100% during that condition.

As mentioned in Section 1.0, the primary spectrophotometer is used to measure the UVT% which then determines the UVT% offset dose. The secondary spectrophotometer unit was programmed as the standby unit for UVT% measurement. The secondary spectrophotometer unit will be used if the primary spectrophotometer measurement is under 30% for 15 minutes. If the value is above 30% for 15 minutes, the UVT% measurement will be used to switch back to the primary controller.

4 RESULTS AND DISCUSSIONS

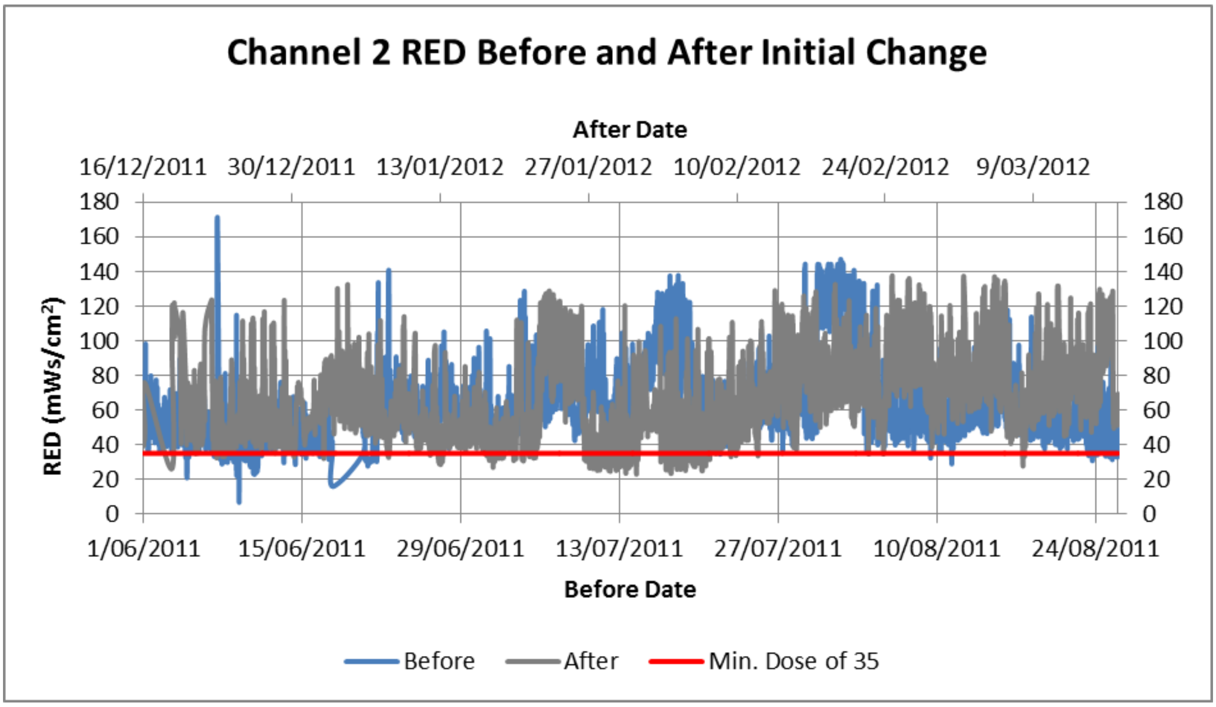
The following table summarises the median for channel 2 UVT% and flow rate over the three period of interest. The conditions of the channel were approximately similar in the three data periods hence comparison between the data sets were considered to be equal.

Table 3: Information for UV channel 2.

Data Period	1/06/2011 to 25/08/2011 – Before Any Change	16/12/2011 to 16/03/2012 – Initial Change	3/12/2012 to 3/03/2013 – Final Change
UVT% Median	60.1	58.4	56.2
UVT% Average	59.9 ± 3.4	58.0 ± 3.8	56.2 ± 2.0
Flow Rate Median	0.50	0.60	0.60
Flow Rate Average	0.6 ±0.1	0.60 ± 0.1	0.60 ± 0.1

Figure 2 shows the RED before any change was implemented to Channel 2 and after the initial change. It should be noted that the plant was controlled based on a PLC based dose for compliance purposes. The data covers an approximate duration of three months for both data sets (1/06/2011 to 25/08/2011 and 16/12/2011 to 16/03/2012).

Figure 2: Channel 2 RED before and after initial change.



From Figure 2, it can be seen that the RED values were showing more values under 35 mWs/cm^2 after the initial change. Figure 3 and 4 show the normal distribution curves before and after the initial change. Before the initial change was implemented, 3.5% of the RED values were less than 35 mWs/cm^2. This increased to 5.3% after the initial change was implemented.

Investigation on the data showed that the RED values were less than 35 mWs/cm^2 because the assist bank was switching off as it was meeting the switch off dose set point. This resulted in insufficient applied dose to meet minimum RED value of 35 mWs/cm^2. As the offset is now varying with UVT%, the assist bank off dose will also vary. If the quality of water is high (UVT% of approximately 58), the offset dose will be low. Therefore the assist bank will switch off at an applied dose rate which is insufficient to provide dose above minimum RED.

Figure 3: RED normal distribution curve before initial change.

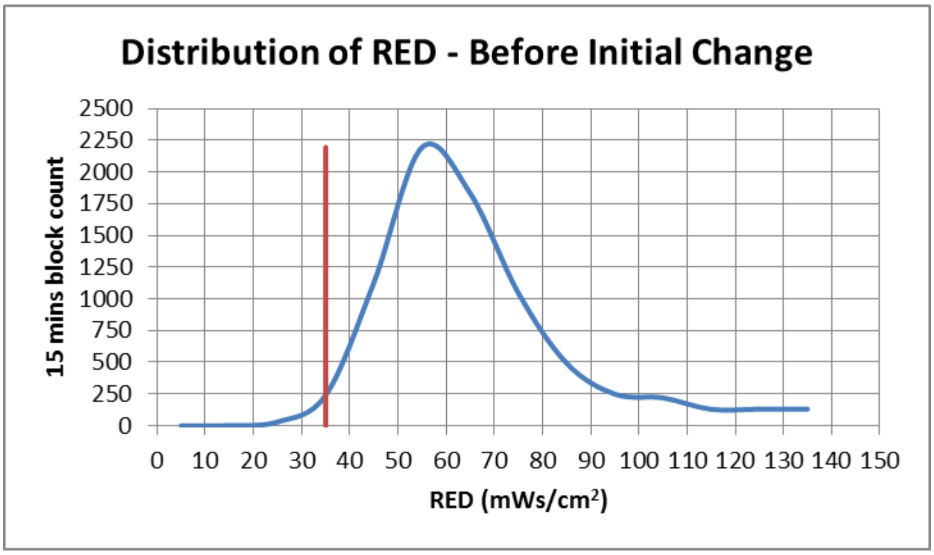
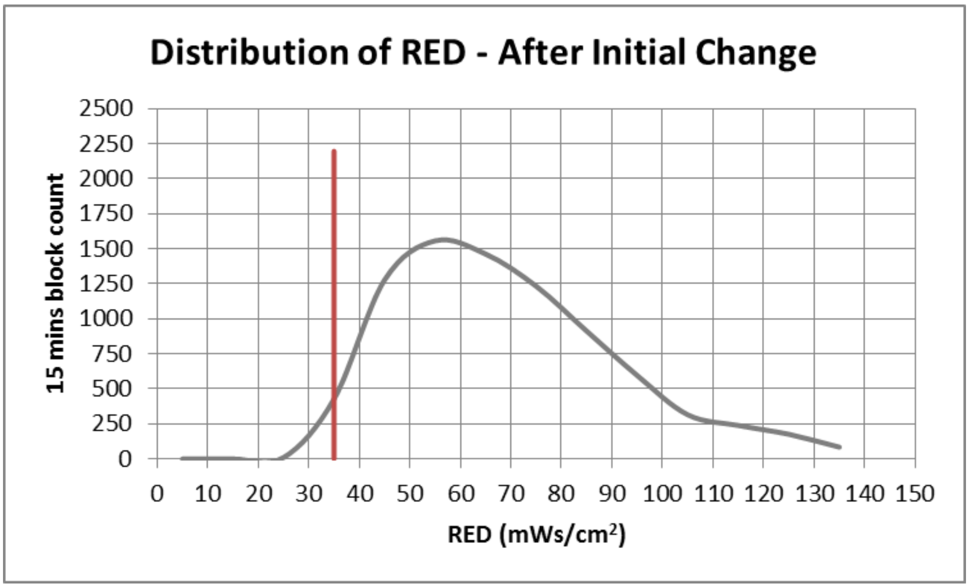


Figure 4: RED normal distribution curve after initial change.



The final change carried out was the addition of another offset labeled as UVT% offset (Refer to Section 2.2). Couple of modifications was done to improve the number of counts RED values are under 35 mWs/cm^2 after the UVT% offset was added. This is discussed in Section 4.1. Figure 5 shows the RED before and after the final change and modifications were done on Channel 2. The normal distribution curve is shown in Figure 6. The data also covers an approximate duration of three months (3/12/2012 to 3/03/2013).

Figure 5: Channel 2 RED before and after additional UVT% offset.

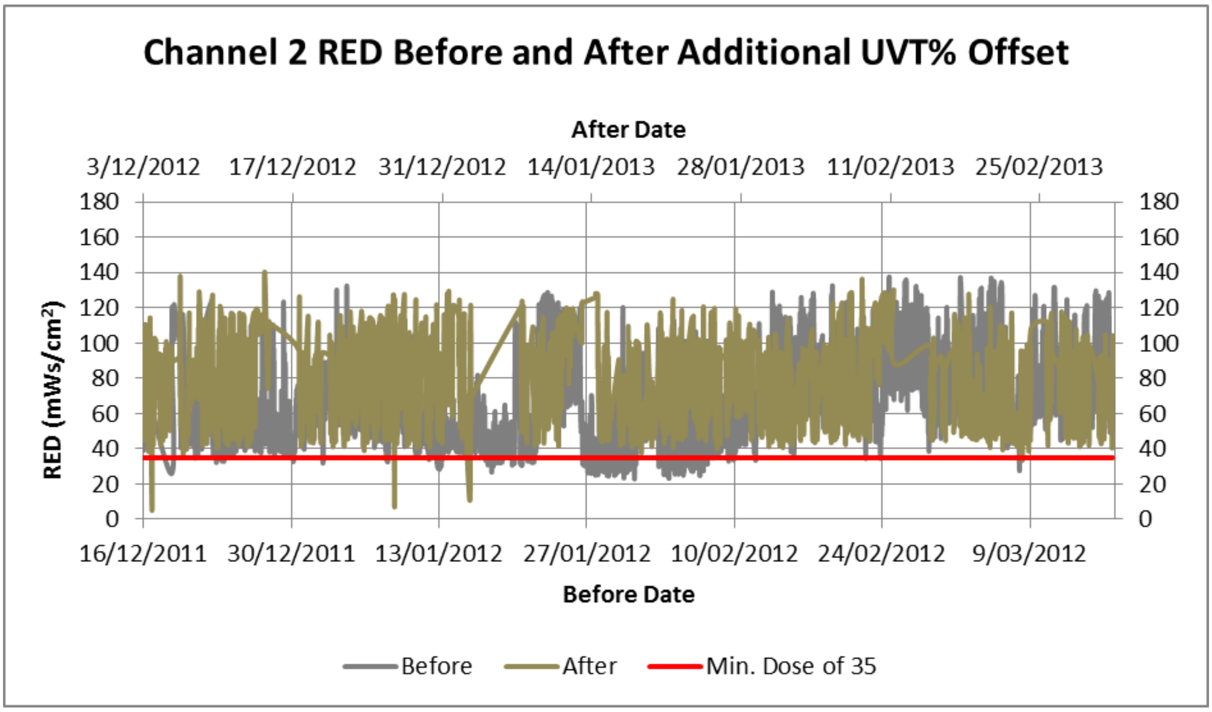
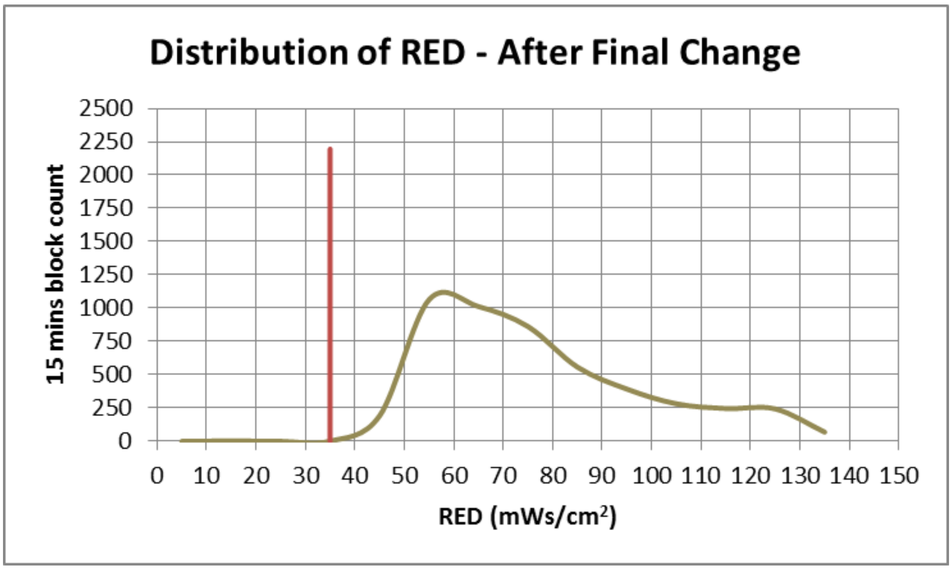


Figure 6: RED normal distribution curve after final change.



From Figure 5, it can be seen a significant reduction in the number of times the RED was below the target 35 mWs/cm^2 after the final change and modifications. Base on the normal distribution curve, 0.1 % of the data were not meeting the minimum 35 mWs/cm^2. The results indicate an improvement over the initial change. Monitoring was carried out until July 2013 and the final algorithm change was implemented in the remaining 11 UV channels at Mangere WWTP.

4.1 MODIFICATIONS AFTER FINAL CHANGE

As mentioned couple of modifications were implemented to reduce the number of 15 minutes average RED values which are less than 35 mWs/cm^2. The aim of the modifications was to enable the assist bank to be switched on at the right time to maintain the RED above the minimum value. The modifications done were UVT% offset dose upper range increased to 45 from 35 mWs/cm^2 and assist bank on dose percentage setpoint from 10 to 20%.

4.2 INSTRUMENT RELIABILITY

An important aspect in utilising the primary spectrophotometer as a control instrument is ensuring the reliability of the measurements. This involves a monthly service by the equipment supplier. The service includes zero check to identify amount of measurement of drift and lens cleaning. Extended maintenance is carried out three times a year which includes sensor checks, voltages, temperature and lamp energy. On a weekly basis, the lens is also cleaned. Besides having scheduled maintenance on the instrument, the operations team is also constantly monitoring the UVT%. If there is more than 5% difference between the primary instrument and the secondary instrument a notification will be raised to have the instrument checked.

5 CONCLUSIONS

It is possible to control a large wastewater treatment plants UV dose based on RED. Reliability and redundancy of measured instruments is vital for control purposes. It is best to have a test channel for initial modifications, where possible, prior to implementing on the entire plant. The algorithm change involved the addition of another dose offset which varies with UVT%. The offset range is from 0 to 45 mWs/cm^2.

Other modifications implemented were increase in assist bank switch on dose percentage setpoint (10 to 20%) and offset dose range (35 to 45 mWs/cm^2). The number of 15 minutes average RED under 35 mWs/cm^2 was reduced to 0.1% from 3.5%.

Values from a secondary UVT% instrument will be used if the primary measurement is under 30% for 15 minutes. If the value is above 30% for 15 minutes, the UVT% measurement will be switch back to the Spectrolyser.

Weekly lens clean and monthly checks are carried out on the spectrolysers to ensure the measurements are reliable.

6 FUTURE WORK

It is planned to procure another online transmittance instrument to provide redundancy at the UV plant. Further refining of the offset dose setpoints will be undertaken to ensure the plant is operated under optimum conditions.

ACKNOWLEDGEMENTS

We would like to acknowledge the members of the independent Disinfection Review Group, Joseph Jacangelo, Gary Groman and Peter Loughran for their ongoing work at Mangere WWTP.

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