Development of a Novel Control Philosophy for UV AOPs in S. Korea

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Introduction

The Siheung Water Treatment Plant (WTP), located in South Korea, is a 101,000 m³/d WTP using flocculation/coagulation followed by sedimentation and sand filtration plus a final chlorination step to produce drinking water from a natural reservoir. The seasonal occurrence of taste and order compounds, such as 2-MIB, over the level of notification, was driving the need for an advanced treatment step. In 2015, the full-scale system consisting of 3 x WEDECO K143 UV low-pressure AOP reactors was validated by an onsite performance test to evaluate the most economic treatment conditions and to establish a control concept enabling the system to react on changing water conditions in real time. The common approach to control UV AOP systems used to be the electrical energy per order (E_{EO}) or electrical energy demand (EED) method. The results of this study will lead to a more sophisticated and energy saving control concept based on the applied UV dose of the system which is measured and controlled online

Materials and methods

The study was carried out using the full-scale UV AOP installation at the Siheung WTP as shown in Fig. 1. Each of the three reactors passed a performance test to demonstrate the required 0.5 log removal of 2-MIB. Different power settings and hydrogen peroxide concentrations were evaluated to remove 2-MIB to below the notification level of 15 ng/L. The flow was adjusted to approximately 1,500 m³/h; hydrogen peroxide and 2-MIB were dosed into the water buffer basin before the UV reactor. While the influent concentration of 2-MIB was fixed to 60 ng/L, different doses of H_2O_2 and UV were applied.

For the verification of the reactor performance, a collimated beam device (CBD) experiment was conducted. The UV doses of the reactor (calculated by the PLC) and the reduction of 2-MIB were compared with the dose response curve established by the CBD experiment (actinometrical). By this the Reduction Equivalent Dose (RED) of the reactor is determined and can be used to control the UV AOP system based on a UV dose approach.

Results

Using the CBD method, the UV dose to achieve a 0.5 log reduction of the 2-MIB was determined to be 324 mJ/cm² with a corresponding hydrogen peroxide dose of 6 mg/L. The full-scale reactor achieved under the same conditions a 0.5 log reduction with a UV dose of 320 mJ/cm² calculated by the reactors PLC, which means that the UV dose shown by the PLC is equal to the RED. This proved that the control logic is capable to deliver, monitor and control exactly the UV dose that is needed according to the UV dose response curve established by the CBD experiment. The UV reactor can be set on a target UV dose and will maintain it independently from the flow rate or UVT changes.

page 18 ▶

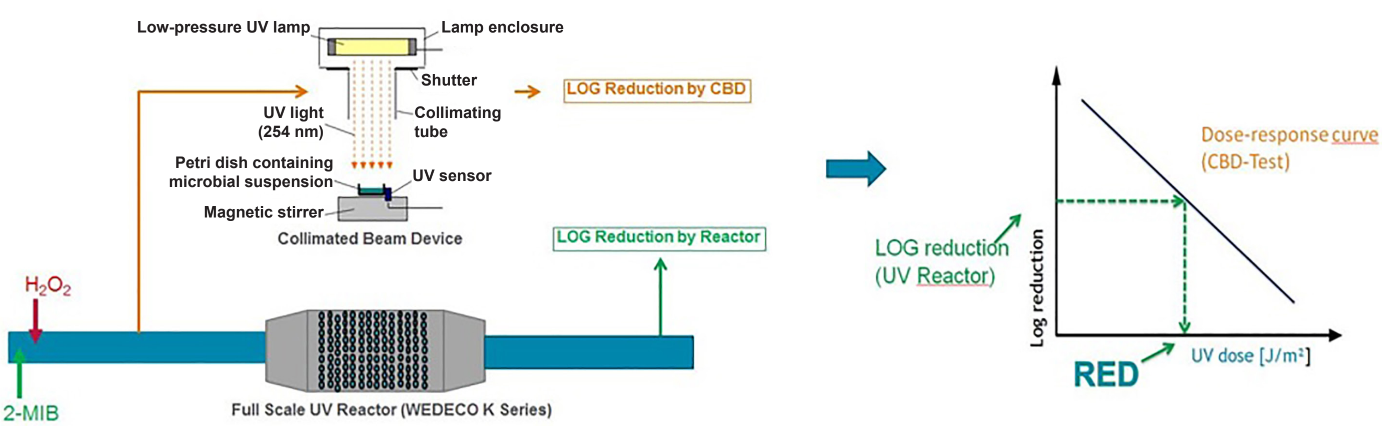

Figure 1. Diagram of the full-scale UV reactor and the collimated beam device (CBD).

◀ page 17

Figure 2 shows the dose response curve of the 2-MIB at a fixed peroxide dose of 6 mg/L and various UV doses applied by the CBD. According to this a UV dose of 324 mJ/cm² is necessary to achieve a 0.5 log reduction of 2-MIB. The log reduction achieved by the UV reactor with a fixed hydrogen peroxide dose of 6 mg/L and various flow rates results in the application of different UV doses calculated by the reactor's PLC. According to the control logic, a UV dose of 320 mJ/cm² is necessary for a 0.5 log reduction of 2-MIB.

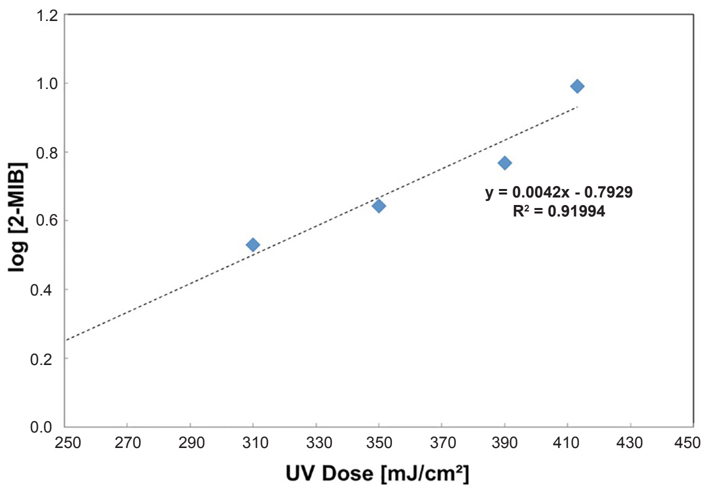

Figure 2. UV dose response curve for 2-MIB for $[H_2O_2]$ = 6 mg/L.

UV dose approach vs. EED/E_{EO}

Compared to the older Electrical Energy Demand (EED) or Electrical Energy per Order (E_{EO}) approach (Bolton et al. 2001) where a fixed power is programmed into the PLC, the UV dose approach allows for operational savings and simultaneously assures 100% compliance with the treatment goal.

Table 1 shows the difference between the EED/E_{EO} approach and the UV dose approach with regards to the energy consumption of the system. The system controlled by UV dose can dim the lamps when the UVT increases and by this significantly save electrical energy.

Table 1. Comparison of EED/E_{EO} and UV dose approaches

UVT	EED (kWh/m³)	UV dose (mJ/cm²)	Power level
93% (design base)	0.039	320	100%
94%	0.039	320	90%
95% (avg. cond.)	0.039	320	75%
98%	0.039	320	50%

The UV AOP PLC controlling the system is based on the UV dose approach. Each reactor row is monitored by a sensor to assure lamps are operating properly and to calculate the UV dose in dependence of the flow rate. With this approach it is possible to react on water quality changes in real time and adjust the UV dose for 100% compliance

Full-scale installation of WEDECO K-Reactors at the Siheung WTP

The system is capable of shutting down lamp rows when less UV is needed, which is the case when no 2-MIB is present and only disinfection is required. This allows for significant costs savings as less energy is consumed and fewer lamps need to be replaced. In addition, the reactors can be upgraded by implementing additional lamp rows.

Conclusions

1. The necessary UV and hydrogen peroxide doses can be established using an on-site CBD experiment.
2. State of the art UV AOP reactors have the ability for an accurate UV dose measurement by utilizing UV sensors inside the UV reactor.
3. UV-based AOPs can be controlled safely using the UV dose approach to assure 100% compliance with the treatment goal.
4. The UV dose approach allows for energy savings when the water quality improves. ■

Reference

Bolton, J.R.; Bircher, K.G.; Tumas, W. and Tolman, C.A. 2001. Figures-of-Merit for the Technical Development and Application of Advanced Oxidation Technologies for both Electric- and Solar-Driven Systems, Pure Appl. Chem., 73(4): 627-637.