Is Scale-Up Applicable for Modular UV Chambers in Drinking Water Applications?

Chengyue Shen[1], O. Karl Scheible[1], Phyllis Posy[2]
1HDR|HydroQual, 1200 MacArthur Blvd., Mahwah, NJ, USA, 07430
[2]Atlantium Technologies, Israel

Key words: *Additivity; Drinking Water; Modularity; Scale-up; Validation;*

INTRODUCTION

When certain criteria are met, appropriate scale-up is traditional for reclaimed water applications, according to the NWRI/WRF UV Guidelines (3rd Edition, 2012). However, both the NWRI guidelines and the US EPA UVDGM have focused on, full-scale validations of UV systems to gain disinfection credit for drinking water applications. With new innovative systems designed as a series of modular chambers, the additivity in dose delivery can be expected by maintaining conservatism with the assumption that the most upstream module would suffer the worst hydraulic condition and the downstream modules would have better performance. As such, validation conducted on a UV system with limited modular chambers can be extended to the same series of UV systems with more chambers. This implies significant savings on validation cost, which is borne by UV manufacturers and the end users.

METHODOLOGY AND RESULTS

The RZ300-1n series and RZ104-1n series reactors from Atlantium Technologies are modular in design and can be configured with one, two or more lamps, where n is the number of lamps in series. The UV lamps are separated from one another by quartz inactivation chambers, located one at each side of the lamp, equivalent to n+1 chambers. There is a UV intensity sensor for each lamp. Theoretically, if the lamp density is defined as , the more lamps installed the higher lamp density per uniform chamber length. Therefore, it is reasonable to expect that an RZ-1(n+1) system would have better disinfection performance than an RZ-1n at the same equivalent operating conditions (UVT, lamp power level, and flow rate per UV lamp).

To demonstrate the validity of this hypothesis, bioassay tests were conducted over a range of reactor configurations for both the RZ300 and RZ104 series, including RZ300-11, RZ300-12 (with one or two lamps in operation), RZ104-11, and RZ104-12 (with one or two lamps in operation). Their performances were compared and analyzed statistically based on their individually developed dose calculation algorithms.

Modularity and Additivity for the RZ300 Series

Validation testing on the RZ300 system has shown that there is no difference between lead and lag lamps, providing significant operating flexibility. Correlating the various tests showed that performance is better with one lamp on in a two-lamp unit (i.e., RZ300-12) when compared to the performance of the single-lamp unit (RZ300-11). Calculations show a more efficient performance as the lamp count increases, so using the RZ300-12 dose algorithm, within the flow and UVT constraints of the validation envelope of the RZ300-12, can be considered a conservative approach. Thus, it is reasonable to expect that an RZ300-1(n+1) system would have better disinfection performance than an RZ300-1(n) at the same equivalent operating conditions of power, UVT and flow rate per lamp. This was tested by comparing the RED algorithms for RZ300-11 and RZ300-12.

First, the dose-calculation algorithm for the RZ300-11 system was used to predict RED for all operating conditions tested with the RZ300-12 system, but halving the flow rate, and then comparing them with the REDs calculated by the dose-calculation algorithm developed for the RZ300-12. Then, the dose-calculation algorithm for the RZ300-12 was used to predict RED for all operating conditions tested with the RZ300-11, but doubling the flow rate, and comparing them with the REDs calculated by the dose-calculation algorithm developed for the RZ300-11. These analyses are shown in Figure 1 and Figure 2. In both cases, the dose algorithm developed for the RZ300-11 predicts an RED lower than that predicted by the dose algorithm for the RZ300-12 at the same equivalent operating conditions.

Modularity and Additivity for the RZ104 Series

Validation testing on the RZ104 system was conducted and similar analyses, as what is shown in Figure 1 and Figure 2, were carried out to compare the performance between the RZ104-11 and RZ104-12 systems. Figure 3 and Figure 4 show these analyses, and again in both cases, the dose algorithm developed for the RZ104-11 predicts an RED lower than that predicted by the dose algorithm for the RZ104-12 at the same equivalent operating conditions.

CONCLUSION

This analysis demonstrates the hypothesis that an RZ300-1(n+1) or RZ104-1(n+1) systems would have better disinfection performance than an RZ300-1n or RZ104-1n at the same equivalent operating conditions. Even though this is based on the validation results of only the RZ-12 and RZ-11 systems, the same logic can apply to other RZ series reactors with more than 2 lamps. It is reasonable, and actually conservative, to predict dose deliveries by an RZ-1n (where n>2) system using the dose algorithm developed for the RZ-12 with appropriate adjustment by using equivalent operating conditions. As long as the dose delivery performance and its additivity can be confirmed, physical validations can be limited to a certain model(s) of UV reactor series designed in modularity to save on validation costs for the entire production line while maintaining conservatism on disinfection credit for public health protection.

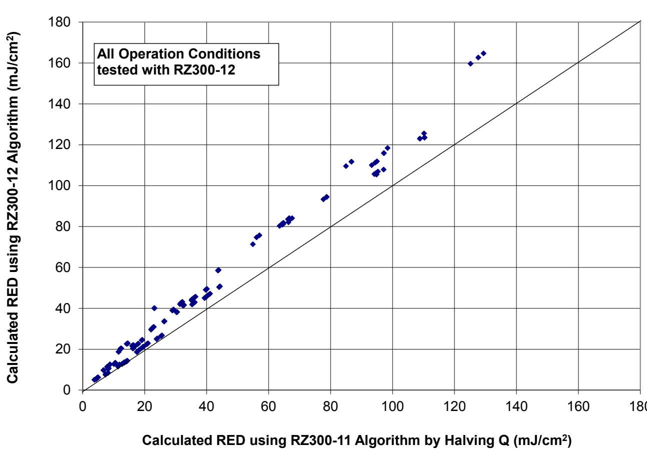

Figure 1. Comparison of Dose-Calculation Algorithms for RZ300-12 and RZ300-11 under All Operating Conditions Tested for RZ300-12. The flow rate is halved when using the RZ300-11 Algorithm.

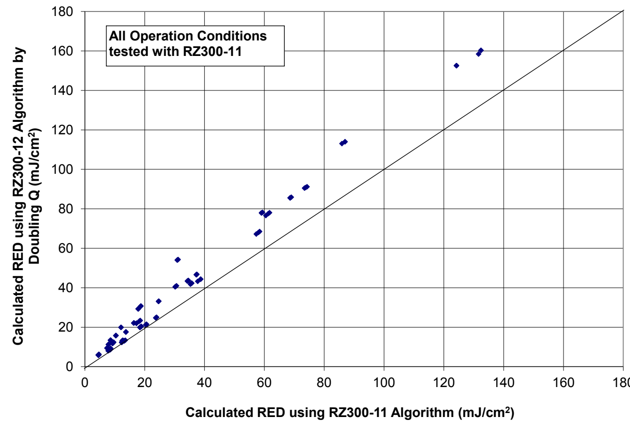

Figure 2. Comparison of Dose-Calculation Algorithms for RZ300-12 and RZ300-11 under All Operating Conditions Tested for RZ300-11. The flow rate is doubled when using the RZ300-12 Algorithm.

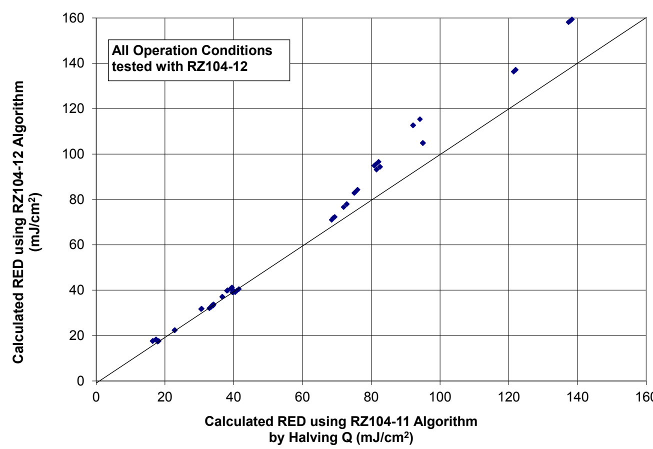

Figure 3. Comparison of Dose-Calculation Algorithms for RZ104-12 and RZ104-11 under All Operating Conditions Tested for RZ104-11. The flow rate is halved when using the RZ104-12 Algorithm.

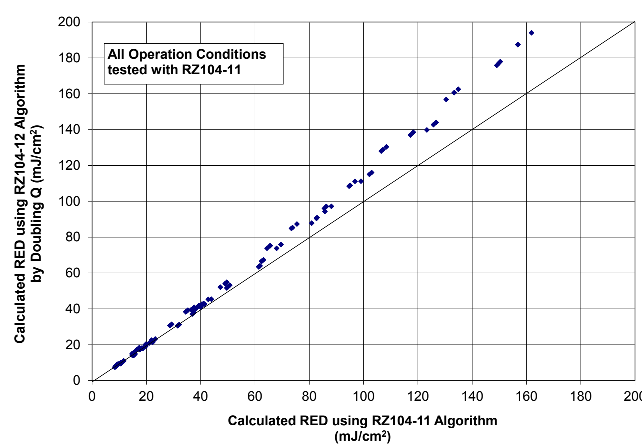

Figure 4. Comparison of Dose-Calculation Algorithms for RZ104-12 and RZ104-11 under All Operating Conditions Tested for RZ104-12. The flow rate is doubled when using the RZ104-11 Algorithm.