

PNWS-AWWA Annual Conference

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# **New UV Sensor Technologies Provide UV Dose Monitoring at Low and High Wavelength for MP UV Systems**

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# Co-Authors

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- ◆ Jeff Adams, USEPA

# Presentation Overview

- ◆ Project Background
- ◆ Advantages and complexities of full spectrum UV light from MP lamps
- ◆ Application of a dual spectrum approach to monitoring MP UV reactors
- ◆ Validation testing and data analysis
- ◆ Benefits of MP UV for Adenovirus inactivation

# Project Background

- ◆ Develop a simplified UV validation approach for virus inactivation per the Ground Water Rule (GWR) for LPHO and MP UV systems
- ◆ Evaluate simplified UV dose monitoring approaches
- ◆ Account for the benefits of low wavelength light from MP UV systems on virus inactivation

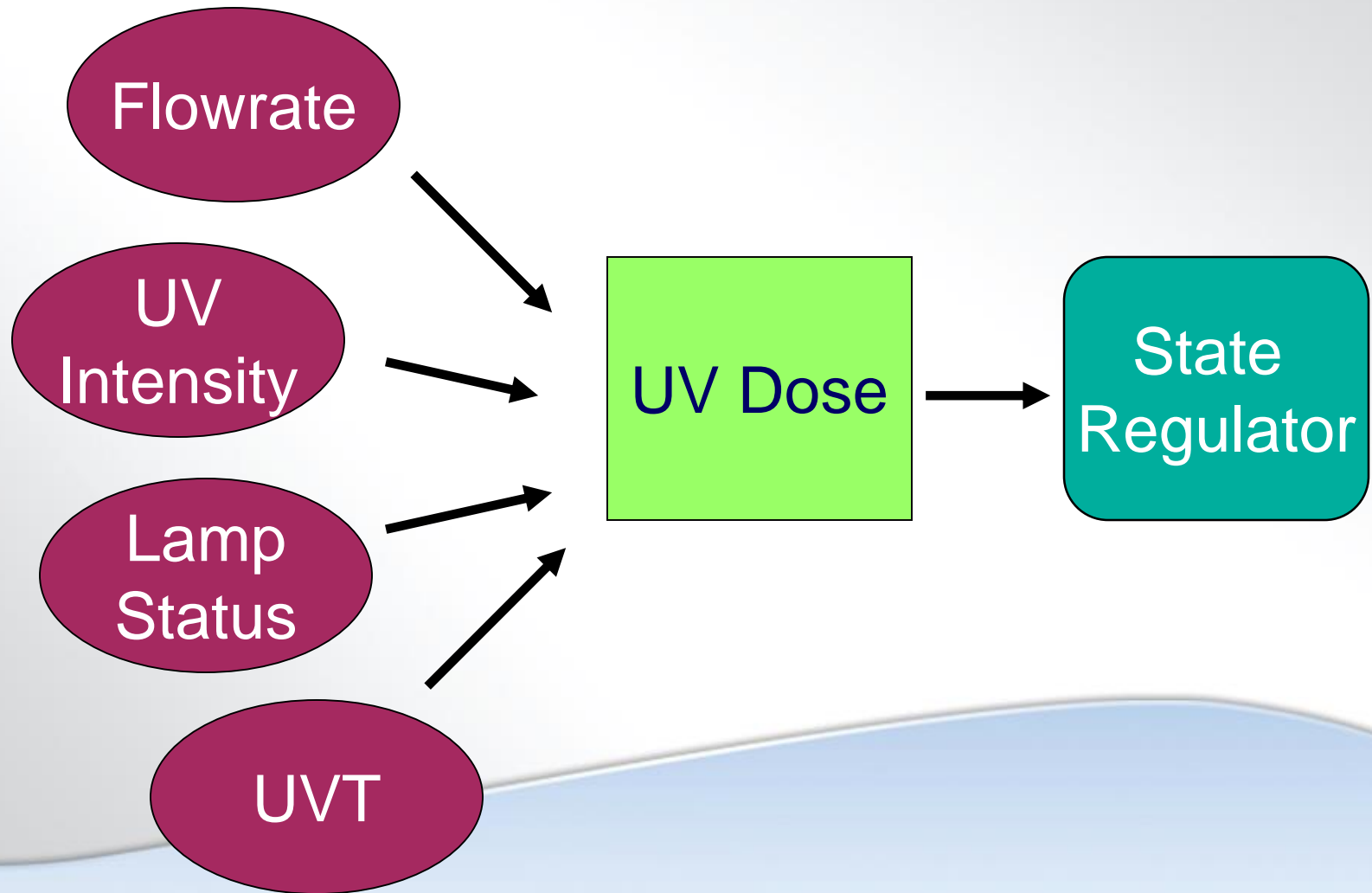
# Disinfection Requirements for Surface and Ground Waters

Pathogen	Required Log Inactivation	
	Surface Water Systems	Ground Water Systems
<i>Giardia</i>	3.0	0.0
Crypto	≥2.0	0.0
<i>Virus</i>	4.0	4.0

# UV dose for virus notably higher than Giardia and Crypto

	UV Dose (mJ/cm <sup>2</sup> ) Required for a Log Inactivation of:							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Crypto	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

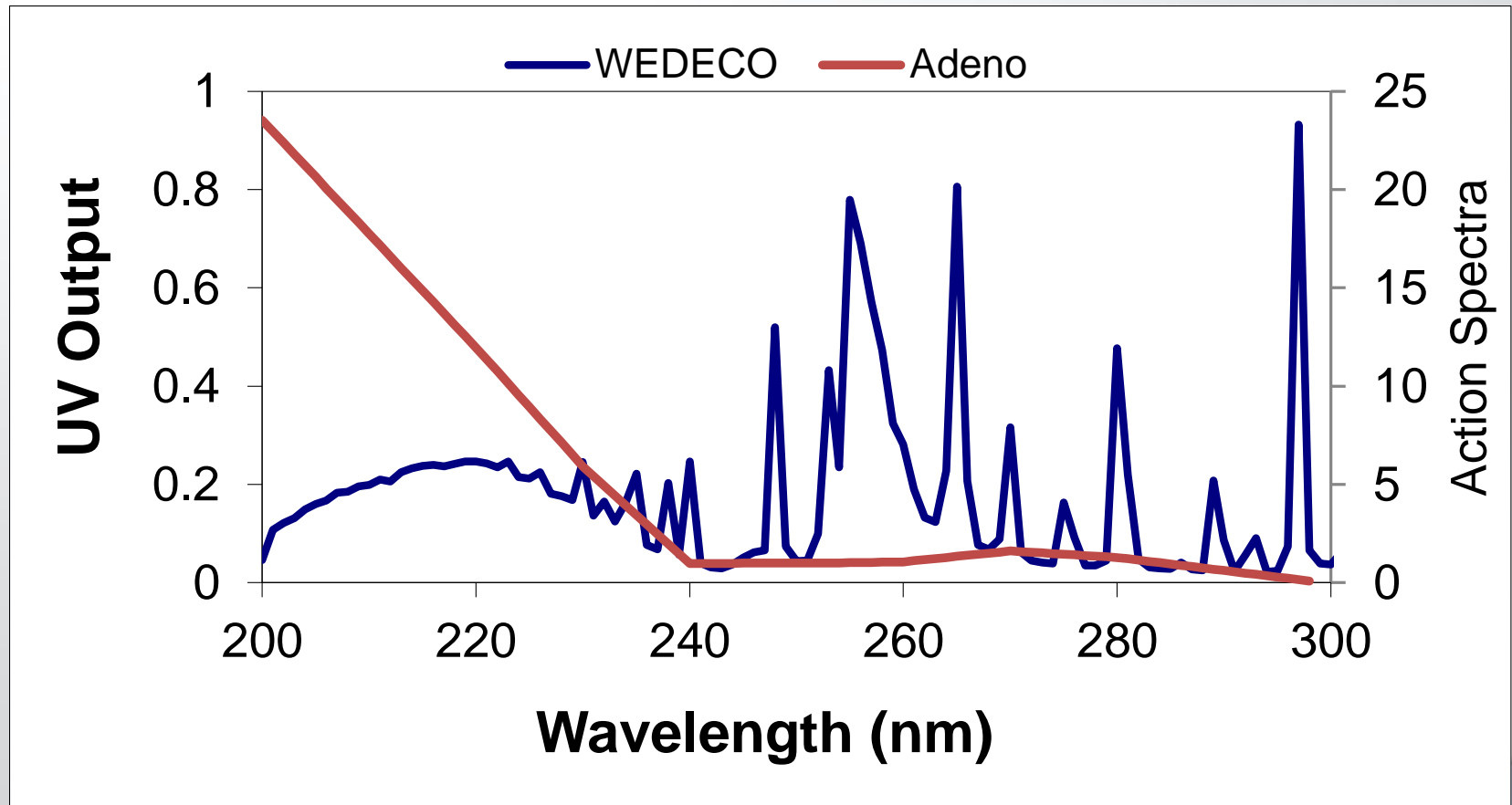
# LT2ESWTR Specifies UV Dose Monitoring for Credit



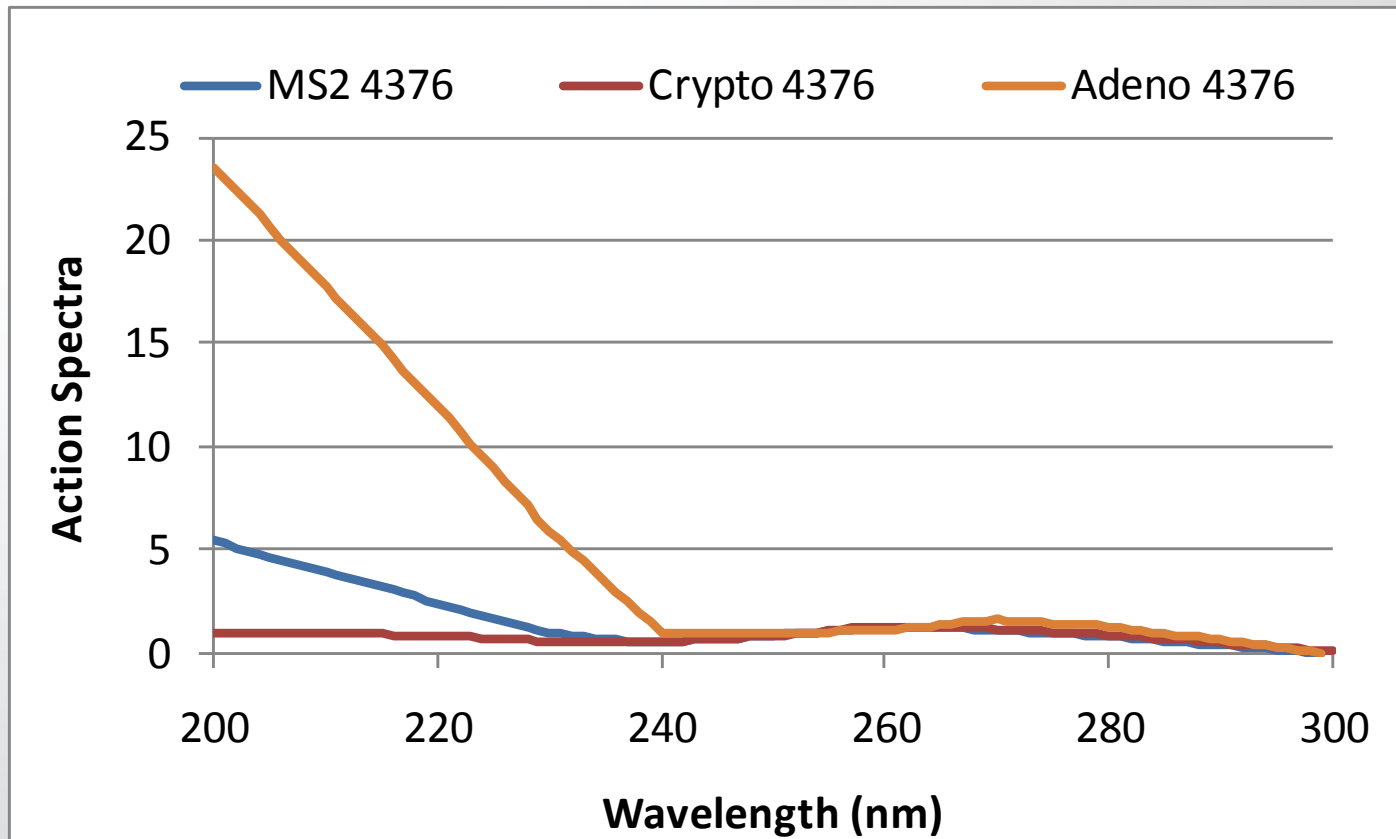
# **Advantages and complexities of full spectrum UV light from MP lamps**



# Adenovirus very sensitive to low wavelength UV light



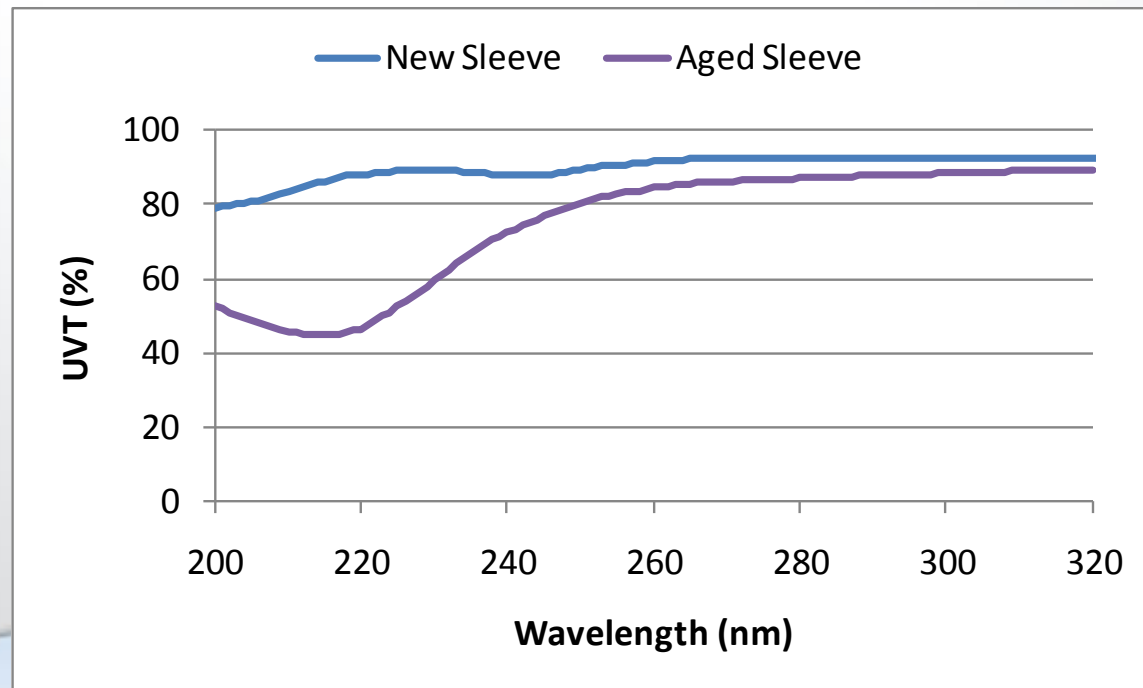
# Action spectra of test organisms differs from target pathogen at low wavelengths



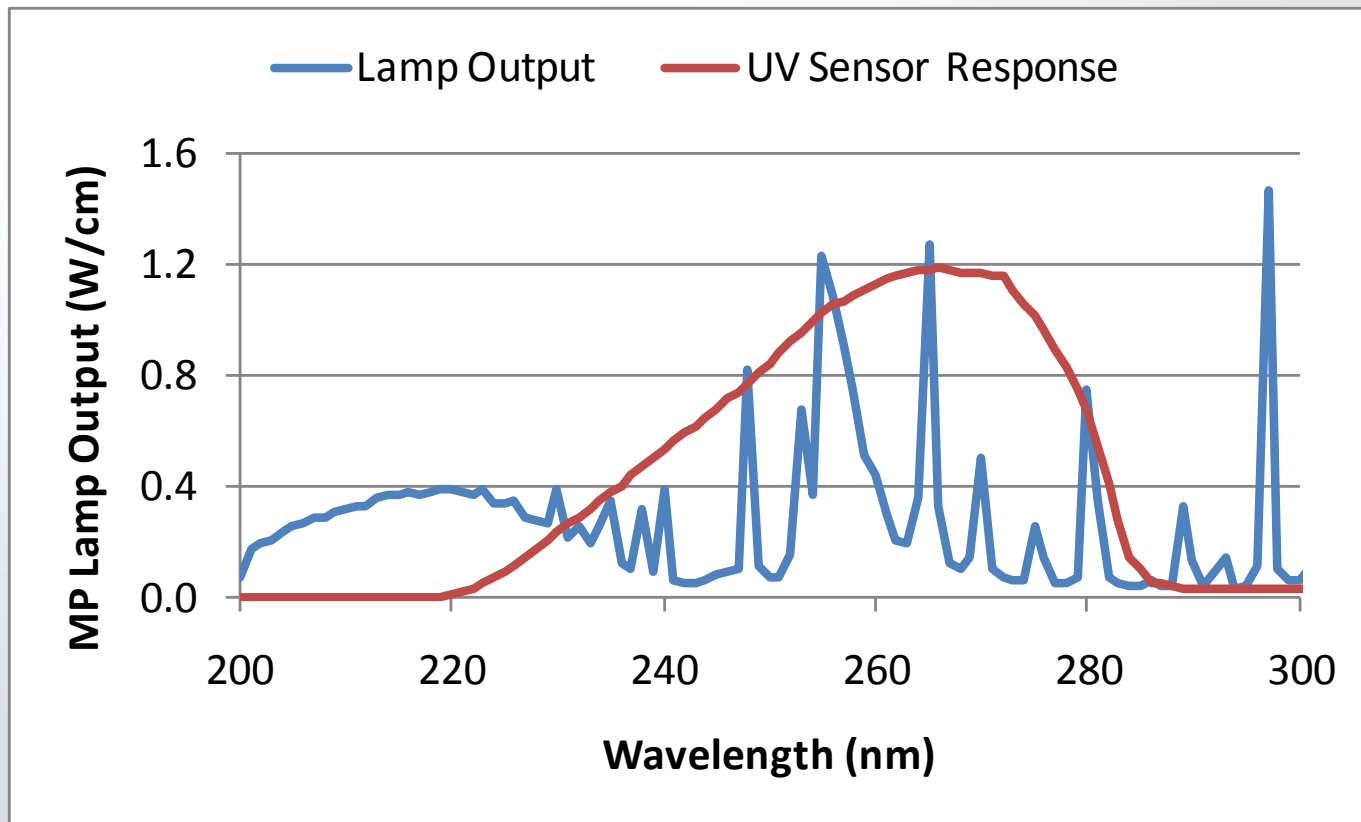
4 log Adeno Credit at MS2 REDs  $\ll$  186 mJ/cm<sup>2</sup>  
if low wavelength light is not blocked

# System performance in the field may differ from validation

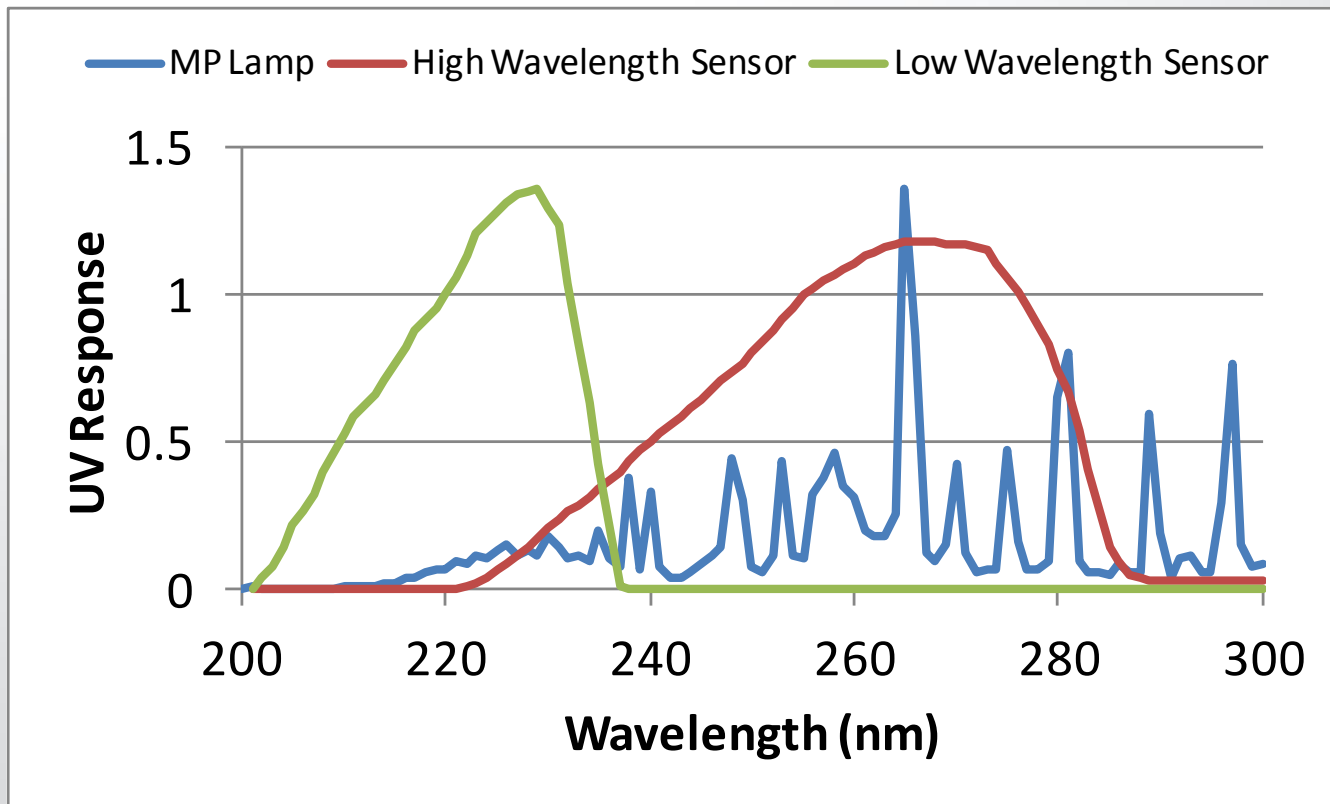
- ◆ Low wavelength benefits observed during validation can go away at WTP due to lamp aging, sleeve fouling/aging, and water UVA spectra



# Standard germicidal UV sensors measure only a portion of the MP UV spectrum



# Dual wavelength UV sensors account for changes in lamp output, sleeve fouling and changes in water absorbance



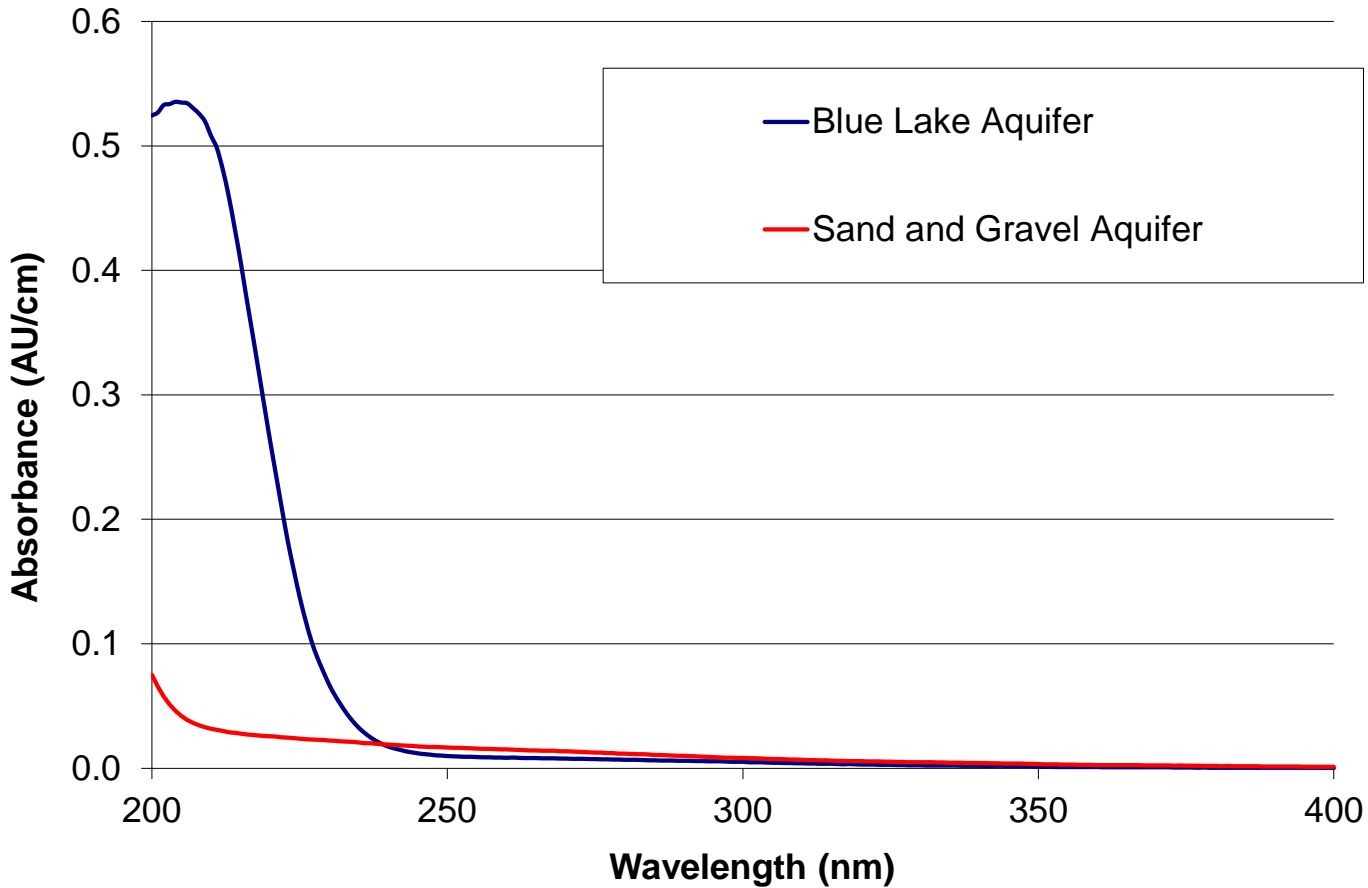
# WEDECO MP validation testing at Portland

- ◆ Single (2 KW) MP UV lamp
- ◆ Dual UV sensor ports
- ◆ Standard ONORM compliant UV sensor to measure high wavelength light
- ◆ Low wavelength sensor to measure wavelengths from <190 to 220 nm

# Validation test matrix designed to maximize spectral differences in UV output

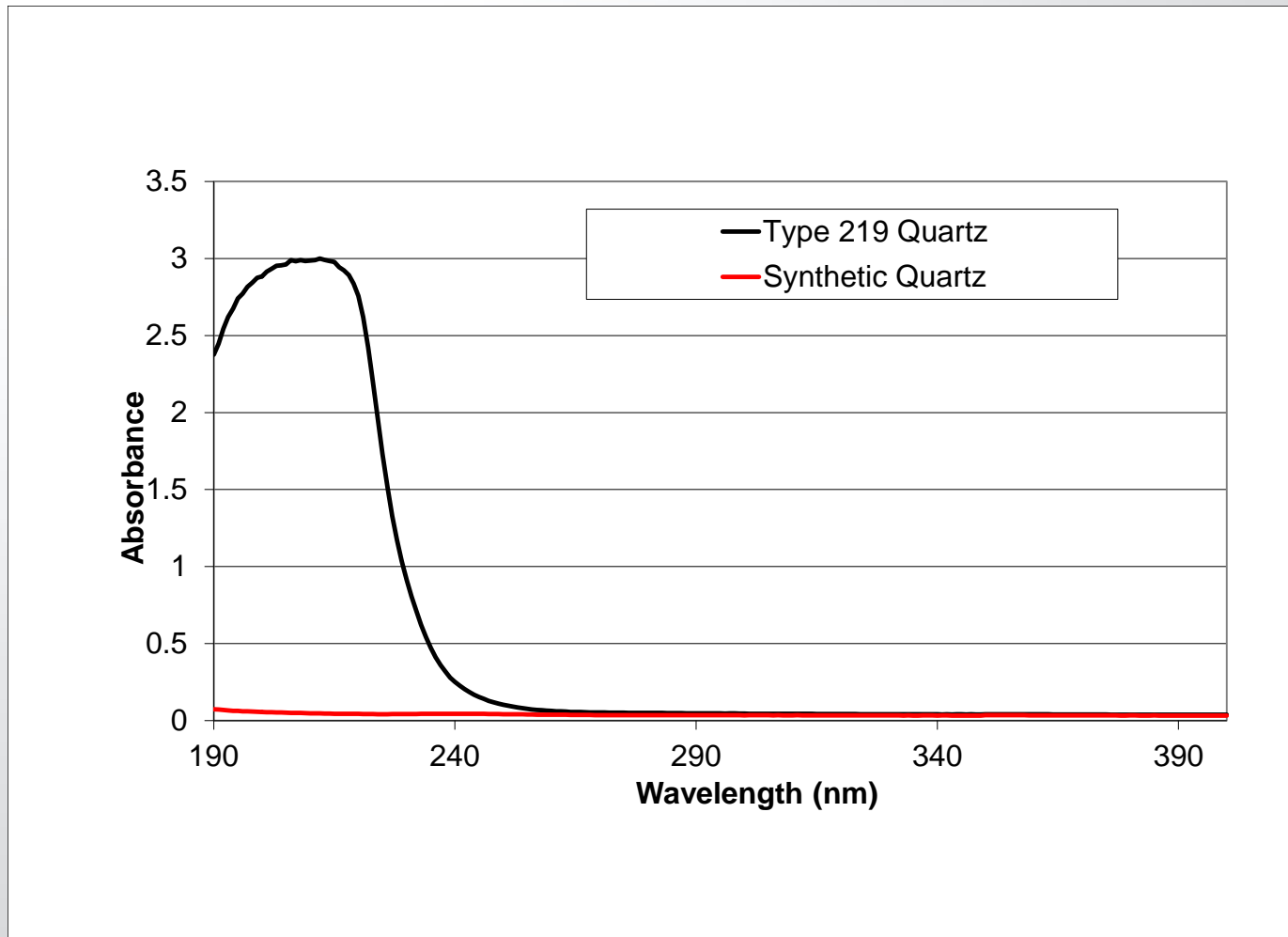
- ◆ Different source waters having different absorbance spectra
- ◆ Synthetic and type 219 Quartz sleeves
- ◆ Superhume and LSA as UV absorbers
- ◆ Test organisms including MS2, *Bacillus pumilus* and adenovirus type II

# Blue Lake and SGA aquifers have different UV absorbance characteristics

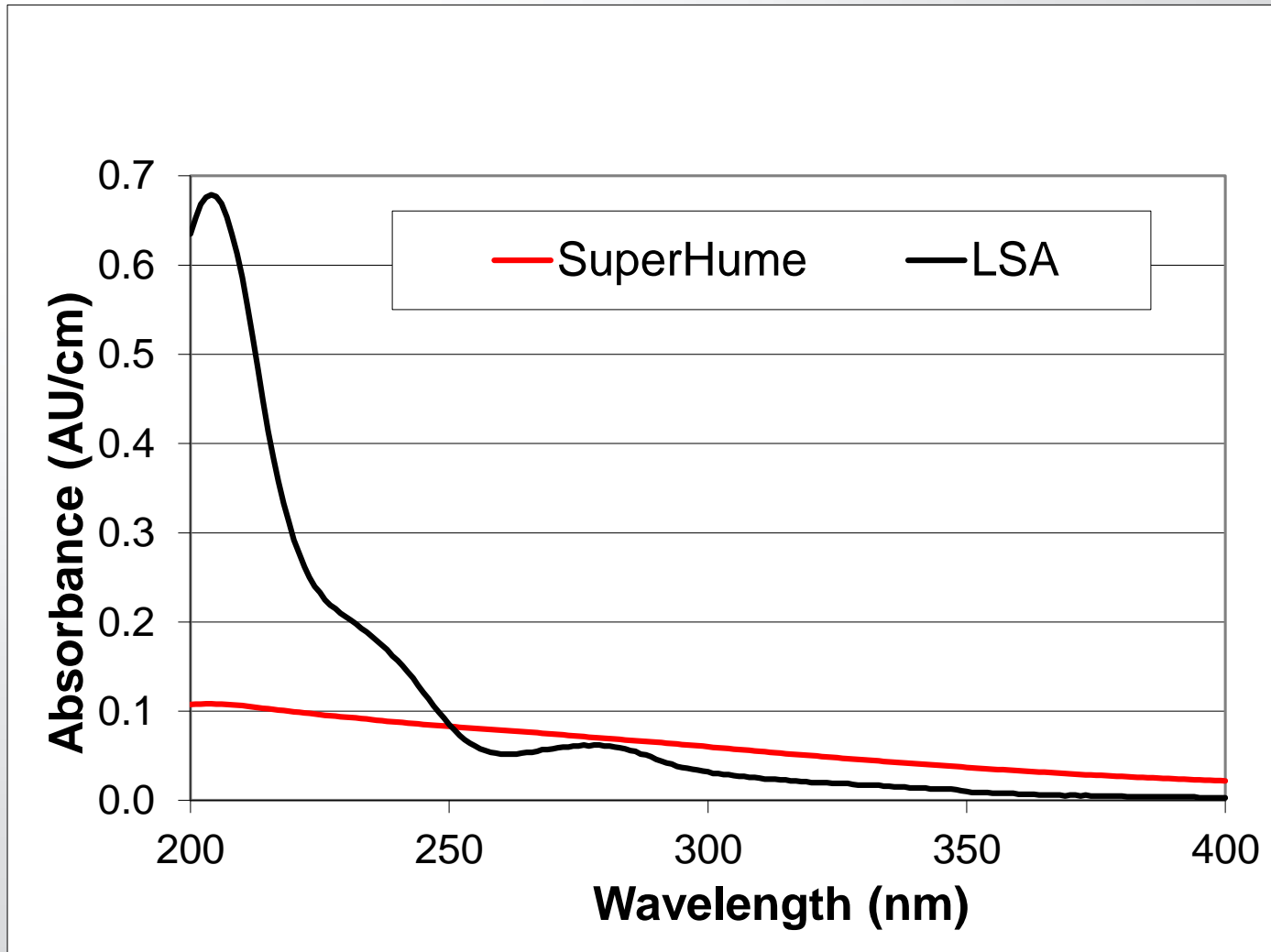




# Type 219 quartz sleeves block low wavelength UV light



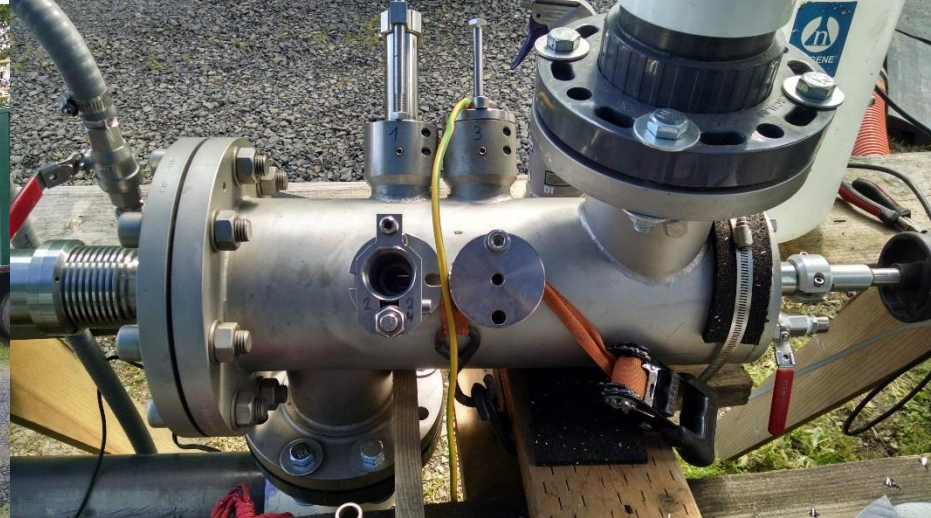
# LSA blocks low wavelength UV light



# **Validation test matrix designed to maximize spectral differences in UV output**

- ◆ Combination of synthetic quartz sleeve, SGA aquifer and SuperHume absorber maximizes contribution of low wavelength UV light.
- ◆ Combination of Type 219 quartz sleeve, Blue Lake aquifer and LSA absorber blocks wavelengths to near zero below 240 nm

# Validation testing conducted at the Portland UV Validation Facility



# Standard validation data analysis uses a master variable

$$\log I = 10^A \times UVA^{B \times UVA} \times \left( \frac{S/S_0}{Q \times D_L} \right)^{C + D \times UVA + E \times UVA^2}$$

Log Inactivation Absorbance

UV

Flowrate

Microbe UV Sensitivity

UV Lamp Output

A, B, C, D, and E – constants defined by UV validation

# New MP UV Dose Equation

$$\log I = \log I_H + \log I_L$$

High Wavelength  
UV Dose Delivery

Low Wavelength  
UV Dose Delivery

# New UV Dose Equation

$$\log I = 10^A \times UVA_{254}^{B \times UVA} \times \left( \frac{S_H / S_{0H}}{D_L \times Q} \right)^{C + D \times UVA_{254} + E \times UVA_{254}^2} \\ + 10^F \times UVA_{220}^{G \times UVA} \times \left( \frac{S_L / S_{0L}}{D_L \times Q} \right)^{H + I \times UVA_{220} + J \times UVA_{220}^2}$$

# New UV Dose Equation

$$\log I = 10^A \times UVA_{254}^{B \times UVA} \times \left( \frac{S_H / S_{0H}}{D_L \times Q} \right)^{C + D \times UVA_{254} + E \times UVA_{254}^2} + 10^F \times UVA_{220}^{G \times UVA} \times \left( \frac{S_L / S_{0L}}{D_L \times Q} \right)^{H + I \times UVA_{220} + J \times UVA_{220}^2}$$

High wavelength UV dose monitoring component uses high wavelength UV sensor and UVT at 254 nm

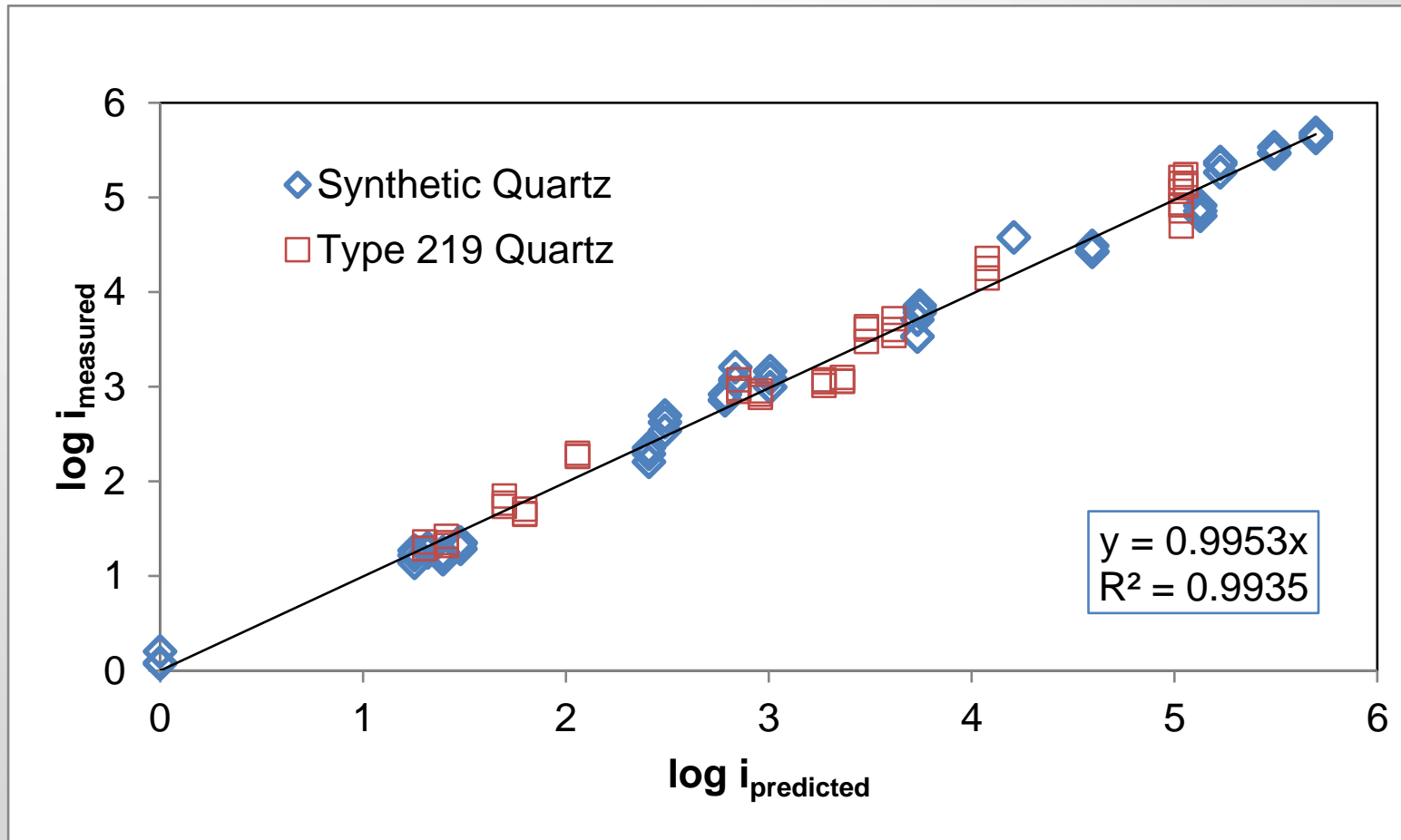


# New UV Dose Equation

$$\log I = 10^A \times UVA_{254}^{B \times UVA} \times \left( \frac{S_H / S_{0H}}{D_L \times Q} \right)^{C + D \times UVA_{254} + E \times UVA_{254}^2} \\ + 10^F \times UVA_{220}^{G \times UVA} \times \left( \frac{S_L / S_{0L}}{D_L \times Q} \right)^{H + I \times UVA_{220} + J \times UVA_{220}^2}$$

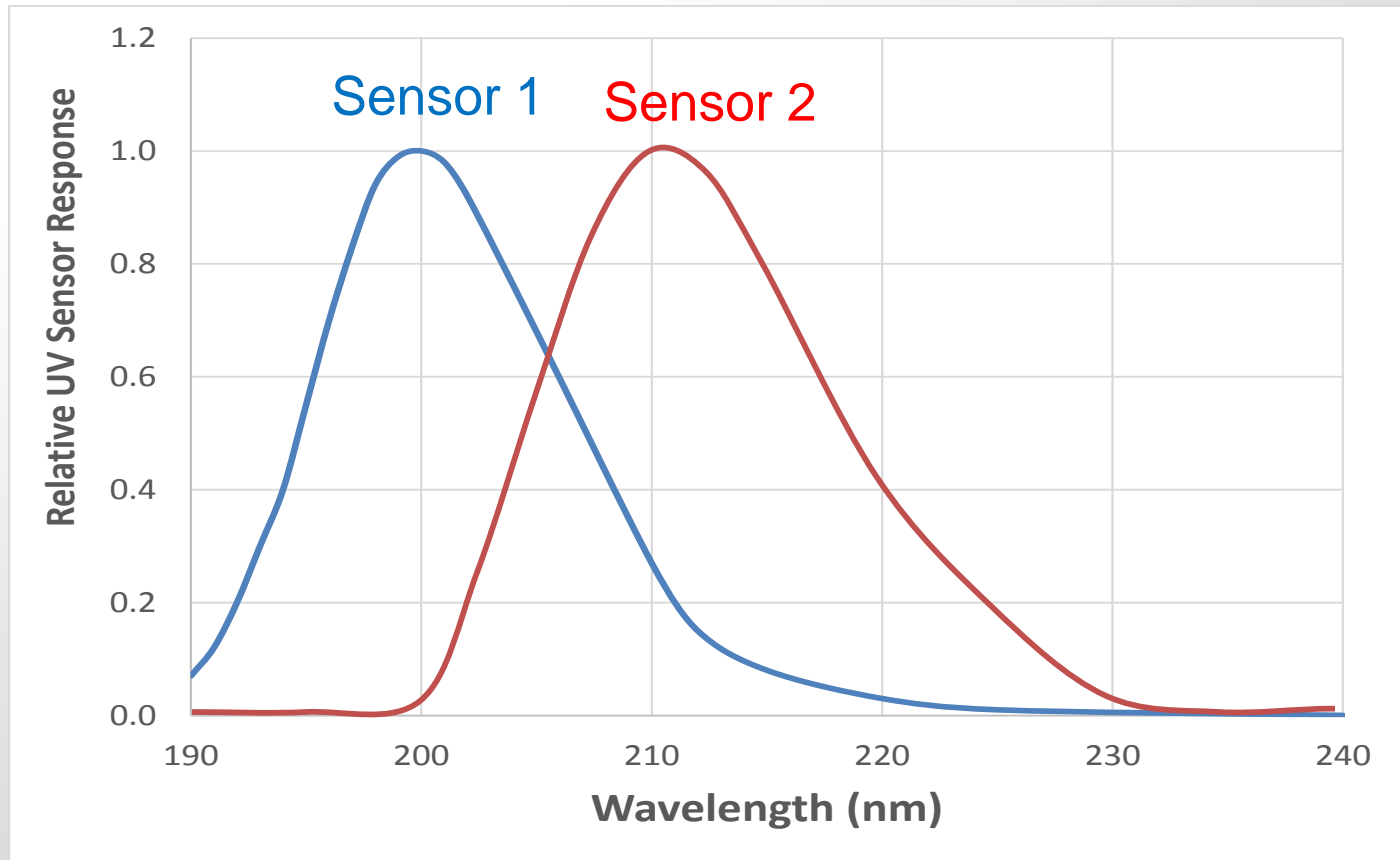
Low wavelength UV dose monitoring component uses low wavelength UV sensor and UVT at 220 nm

# New dose model predicts MS2 inactivation

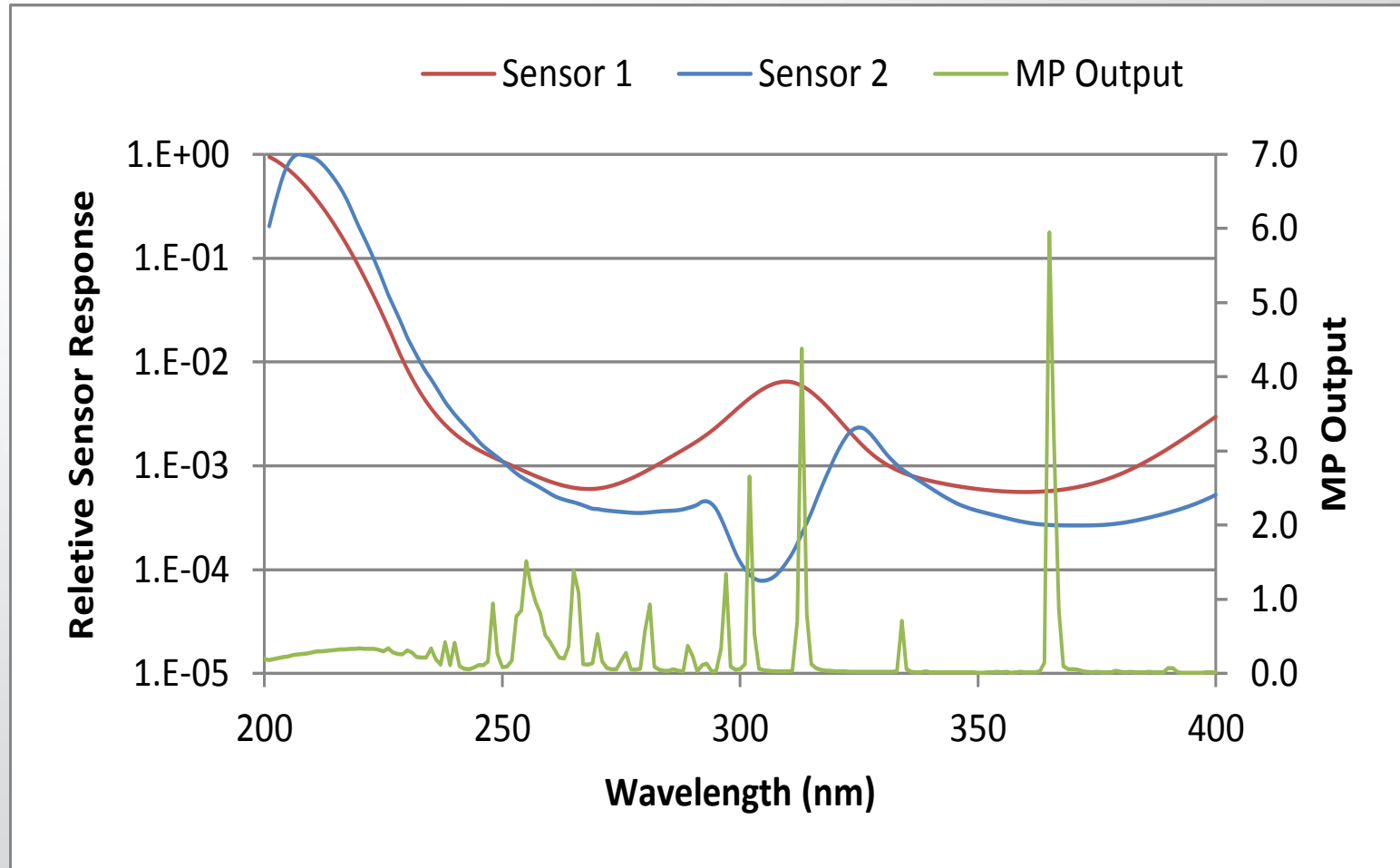


# **Spectral Response of Low Wavelength Sensors is Critical**

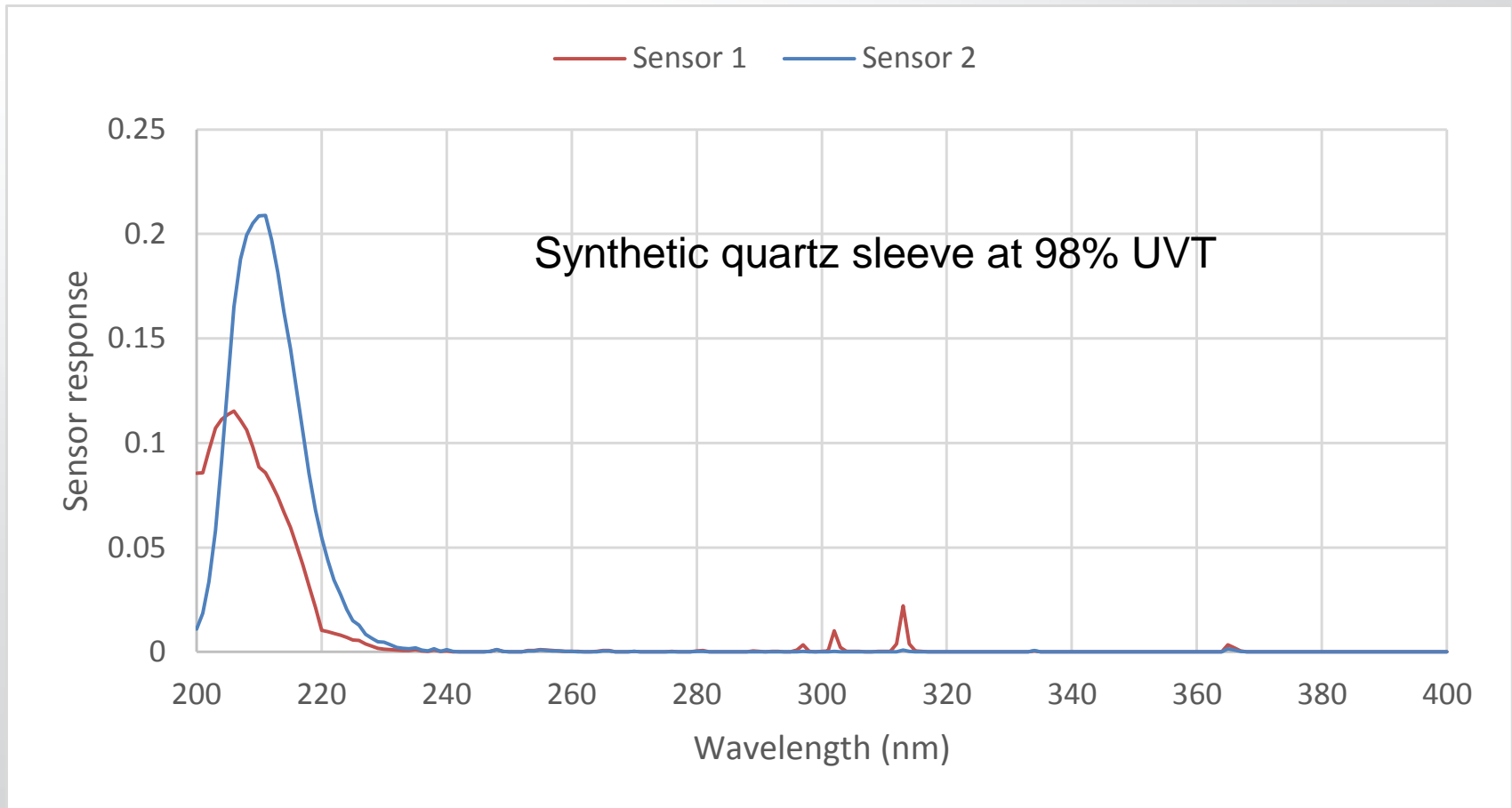
# Two low wavelength sensors have different spectral response



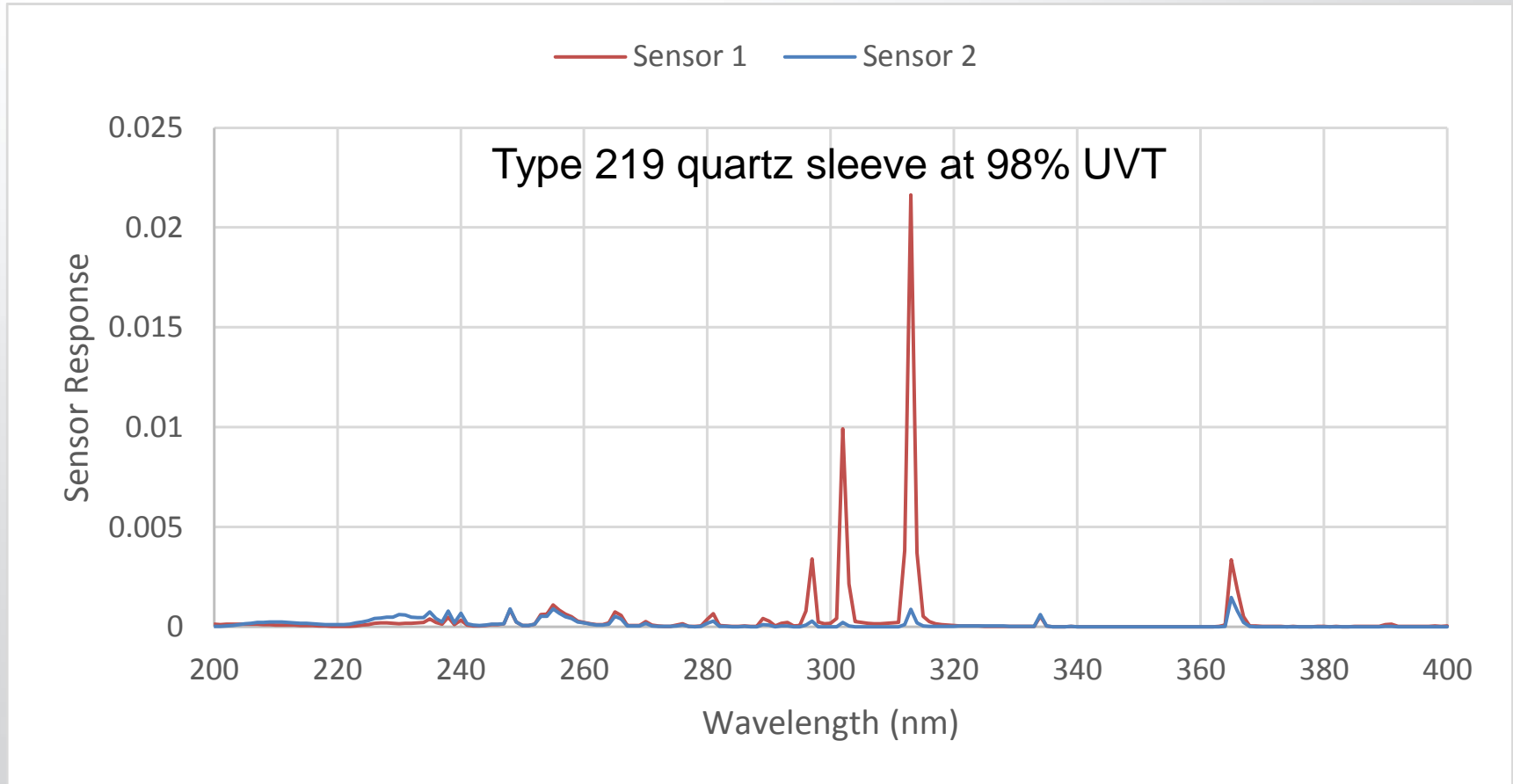
# Secondary peaks in spectral response give misleading results



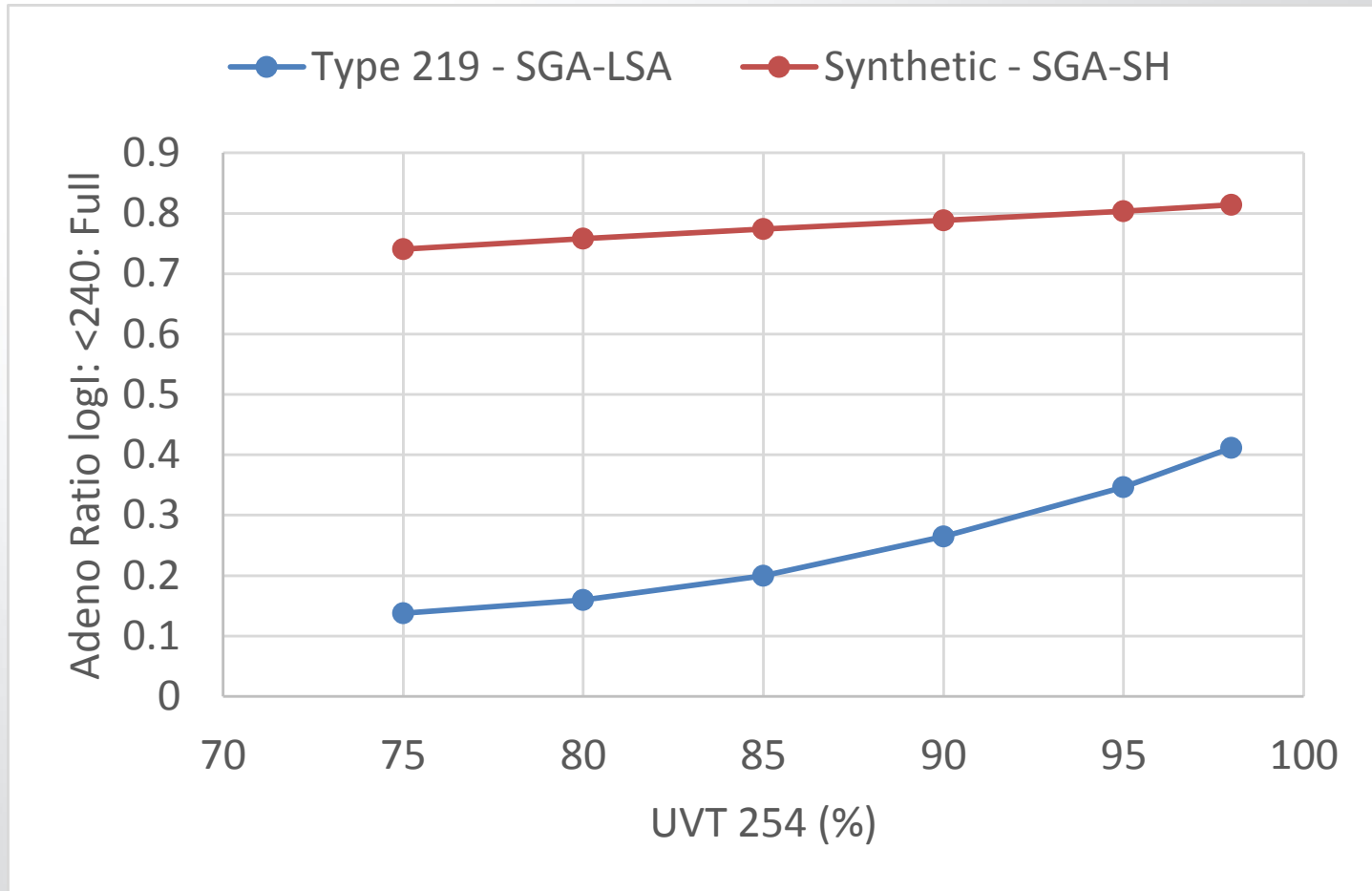
# Calculated spectral response with full spectrum light



# Calculated spectral response with low wavelength light blocked



# Low wavelength benefits for adenovirus inactivation are significant



Based on Project 4376 ASCFs for Validation Using Adenovirus



# Conclusions

- ◆ MP UV light offers significant benefits for adenovirus credit in certain waters
- ◆ Taking advantage of benefits requires monitoring of low wavelength UV light
- ◆ Dual wavelength models for predicting microbial inactivation in MP UV system show promise
- ◆ Low wavelength UV sensor need to have the appropriate spectral response
  - Beware of secondary peaks

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# Questions?

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