Spectral Irradiance Measurement and Actinic Radiometer Calibration for UV Water Disinfection

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In a joint project, sglux and PTB investigated and developed methods and equipment to measure the spectral and weighted irradiance of high-efficiency UV-C emitters used in water disinfection plants.

A calibration facility was set-up to calibrate the microbicidal irradiance responsivity of actinic radiometers with respect to the weighted spectral irradiance of specially selected Hg low-pressure and medium-pressure UV radiators.

To verify the calibration and to perform on-site tests, spectral measurements have been carried out directly at water disinfection plants in operation. The weighted microbicidal irradiance of the plants was calculated and compared to the measurements of various actinic radiometers.

INTRODUCTION

More and more water disinfection systems are equipped with high-efficiency UV emitters which have to fulfil special requirements for their spectral irradiance. A high irradiance should be achieved in the spectral range covering the microbicidal action spectrum between 240 nm and 290 nm, whereas below 240 nm, the irradiance should be low, in order to avoid any possible photochemical processes leading to by-product formation.

Actinic radiometers [1] monitor UV radiators, but they cannot provide any information on the spectral distribution of the radiators in the plants.

The radiometer response has to represent the weighted microbicidal irradiance of the UV emitters. However, the spectral responsivity does not exactly match the microbicidal action spectrum and the readout of the radiometer has to be corrected by its spectral mismatch. The direct spectral responsivity calibration of such actinic radiometers is very limited due to the high spectral power needed for such measurements. Thus, a calibration facility has been constructed, where actinic radiometers are calibrated with respect to the spectral irradiance of typical high-power UV sources.

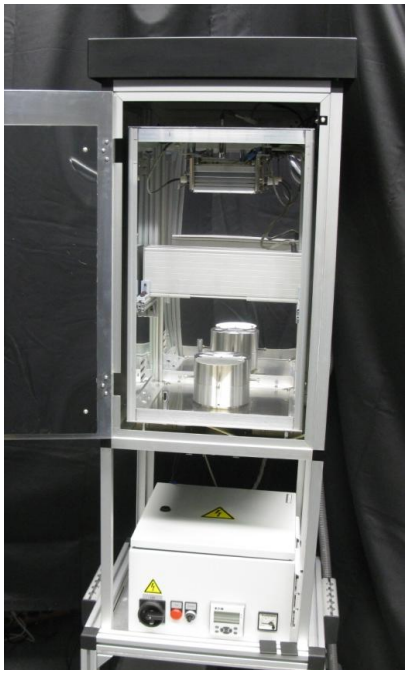

Figure 1. The transfer standard for high-power UV irradiance.

THE CALIBRATION FACILITY

Commercially available UV radiators designed specifically for UV disinfection have been characterized, and their suitability as a calibration standard has been investigated [2]. To calibrate sensors for UV water disinfection plants based on Hg medium-pressure emitters as well as on Hg low-pressure sources, a 1000 W medium-pressure lamp and a 40 W low-pressure lamp were selected.

The Hg medium-pressure lamp is mounted on top of a ventilated cabinet and the Hg low-pressure can be mounted underneath (Fig. 1). A UV sensor mounted at the bottom of the cabinet can hold actinic radiometers to be calibrated as well as specially designed entrance optics of spectroradiometers. The spectral irradiance $E_S(\lambda)$ of the UV sources is measured using an array spectroradiometer as well as a fast scanning double monochromator system.

The measured spectra are shown in Fig. 2 compared to the spectral irradiance distribution of typical standard lamps.

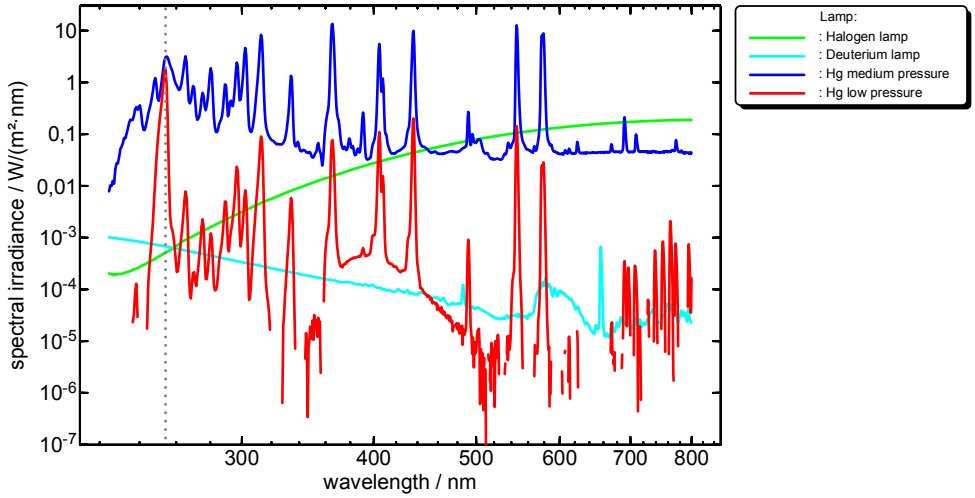

Figure 2. Spectral irradiance of classical standard lamps compared to the high-power UV transfer standard lamps.

Weighted with the microbicidal action spectrum $a_{\mathrm{mic}}(\lambda)$, the microbicidal irradiance $E_{\mathrm{mic,S}}$ of the Source S can be calculated and actinic radiometers are calibrated with respect to the weighted irradiance

$$E_{micS} = \int a_{mic}(\lambda) \cdot E_S(\lambda) d\lambda \qquad (1)$$

ON-SITE SPECTRAL MEASUREMENTS

Traceable spectral measurements of high-power UV sources are rather challenging. The spectral irradiance of such radiators is higher by several orders of magnitude than the spectral irradiance of typical transfer standard lamps. Therefore, two spectroradiometers have been adapted to measure high irradiances.

The entrance optics of the fibre-coupled instruments have been constructed similarly to that of the actinic radiometers [4]. Density filters inside the spectroradiometers allow the attenuation of the incoming radiant power by up to three orders of magnitude. Combined with the high dynamics of the spectroradiometers they were calibrated using deuterium lamps and quartz halogen lamps.

For the first time, spectral measurements directly on UV disinfection plants in operation were carried out. Water disinfection systems using both types of UV emitters were measured at the DVGW test centre in St. Augustin, Germany [3]. The resulting calculated microbicidal irradiances agreed well with the measurements of the reference radiometers used at the test centre.

Additional measurements of different reference radiometers at the new calibration facility confirmed the source-based calibration method.

CONCLUSION

Direct spectral measurements allow the examination of new water disinfection systems and radiator types. Combined with new UV transfer standard sources it is possible to calibrate broadband actinic UV radiometers in terms of microbicidal irradiance responsivity.

ACKNOWLEDGMENTS

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