

# Refining The Fluence (UV Dose) Calculation For Polychromatic Ultraviolet Disinfection Reactors

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## Background

The introduction of DWI guidelines (2010) for ultraviolet disinfection (UV) has facilitated the application of this technology for UK water companies. UV reactors are required to be validated using a challenge microorganism following a prescribed protocol such as that of the USEPA (2006). The most common test organism used in this validation is MS2 phage.

Medium pressure (MP) mercury based lamp technology enables a high power density across a broad polychromatic output the germicidal region being 200-300nm. The current known UV sensitivity for MS2 phage (also called 'action spectrum') includes some uncertainty particularly below 230nm. Furthermore. MP emission spectra used in literature do not have a significant output below 220nm such as that presented by Guo, Hu and Bolton (2008) (see Fig 4).

## Aims

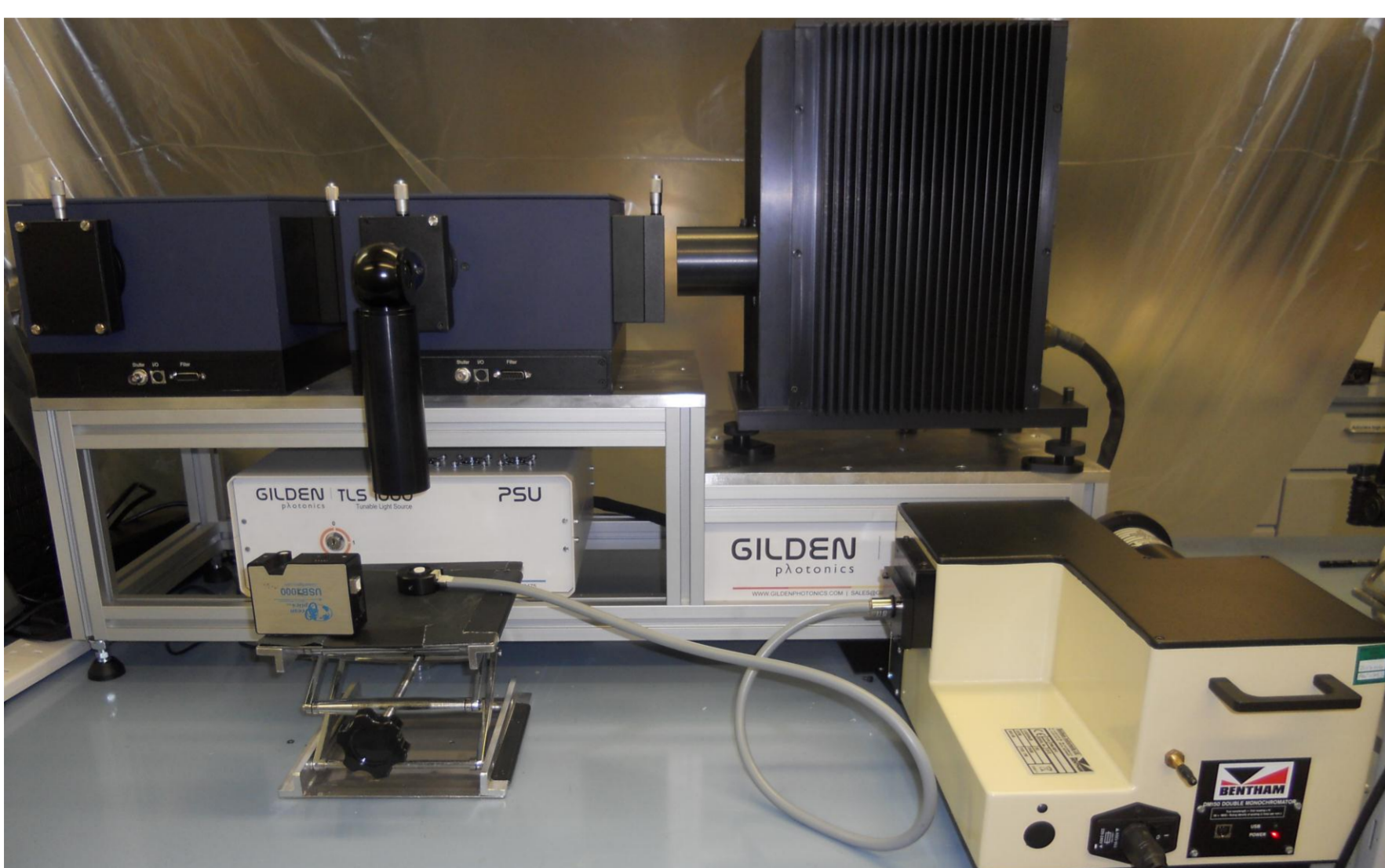
1. Investigate current methodology relating to medium pressure UV collimated beam and MS2 action spectra protocol
2. Produce a high resolution action spectrum for MS2 phage
3. Incorporate the new action spectrum into MP UV Fluence calculations and quantify the magnitude of impact of low wavelength sensitivity on UV fluence

## Methods

Calibrated spectroradiometers Bentham DM150 and Ocean Optics 2000 (Fig 1) were used to investigate MP collimated beam irradiance by measuring:

1. Spectral transmission of quartz window at varying temperatures
2. Spectral emittance when reducing Hg pressure by air cooling
3. Spectral emittance of lamp in relation to angle from the horizontal

Fig 1; Spectral Equipment, OO 2000 (bottom left), DM150 (bottom right), tuneable light source (rear)



## References

Bolton, J. and Linden, K. (2003) 'Standardization of methods for fluence (dose) determination in bench-scale UV experiments', *Journal of environmental engineering*, vol. 29, no. 3, March, pp. 209-215.

Guo, M., Hu, H. and Bolton, J. (2008) 'Sensor factor correction for collimated beam experiments using a medium pressure ultraviolet lamp', *Journal of environmental engineering*, vol. 7, pp. 677-679.

United States Environmental Protection Agency (USEPA) (2006) Ultraviolet disinfection guidance manual for the final long term 2 enhanced surface water treatment rule, EPA 815-R-06-007, Office of Water (4601), Washington DC 20460, USA.

## Results

Quartz transmission across 200-300nm was measured at increasing temperatures due to lamp heating with no variation measured. Spectral output had significant spectral variation in relation to angle (Fig 3). Further tests revealed arc instability which is indicative of internal gas turbulence rather than temperature. A first generation of improved lamps was designed (Fig 4) with a second generation now being constructed. Thus we now have a lamp design which spectral output inclusive of <220nm providing a suitable light source for determining the sensitivity of MS2 phage to low wavelengths.

Fig 2; Spectral emittance in relation to temperature/internal mercury pressure

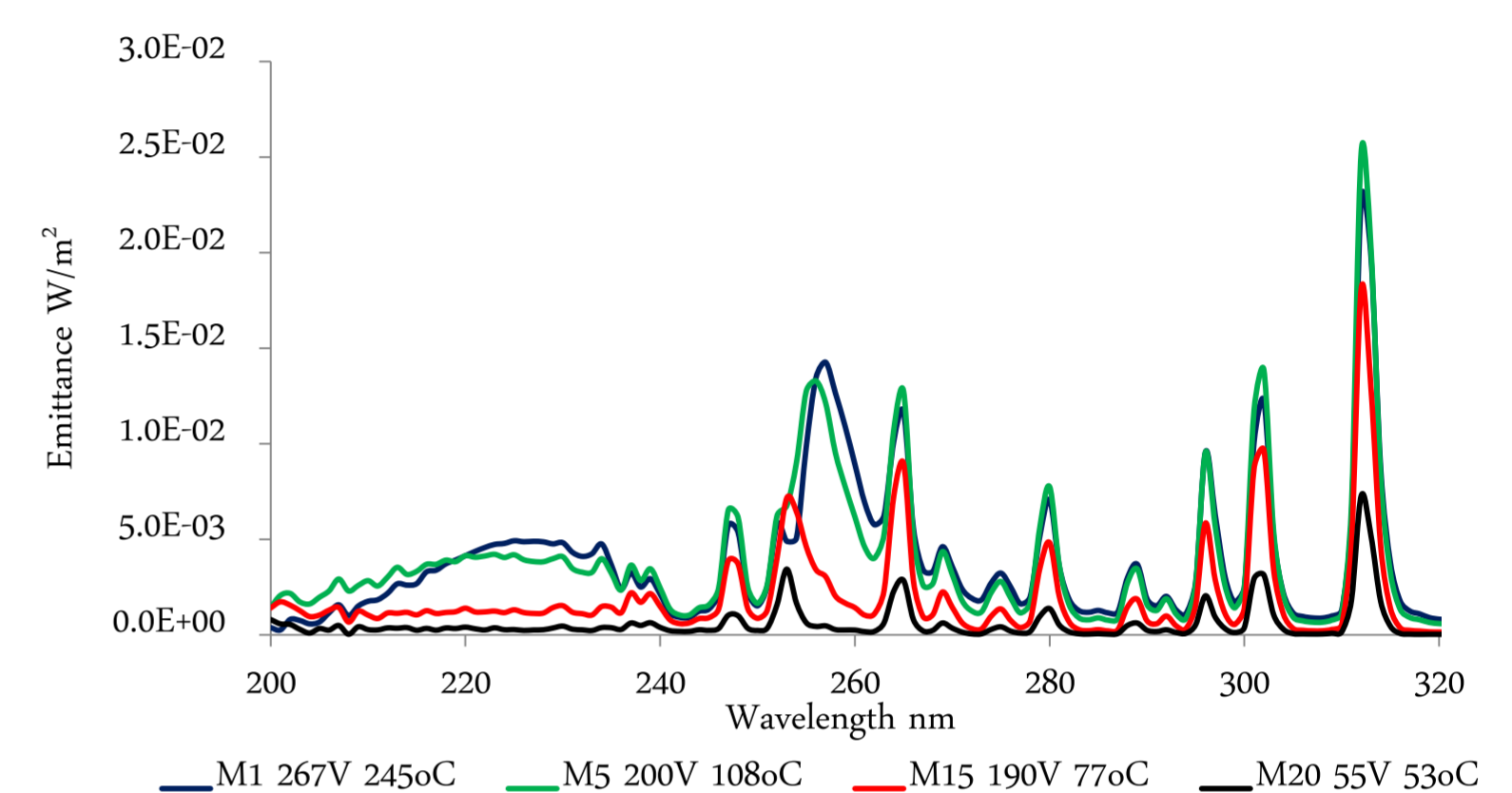


Fig 3; Change in spectral emittance in relation to angle 90° being above lamp -90° being below

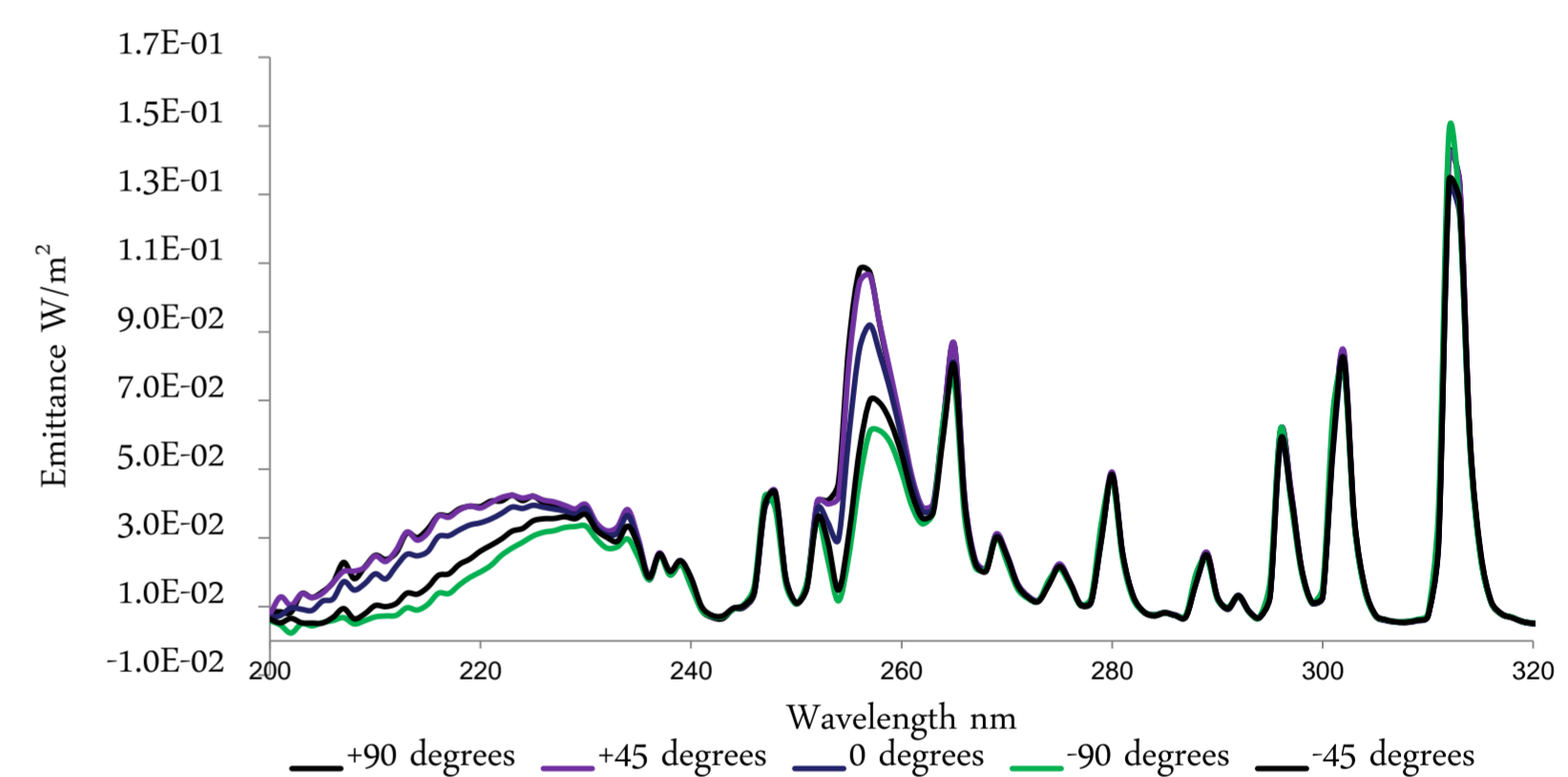
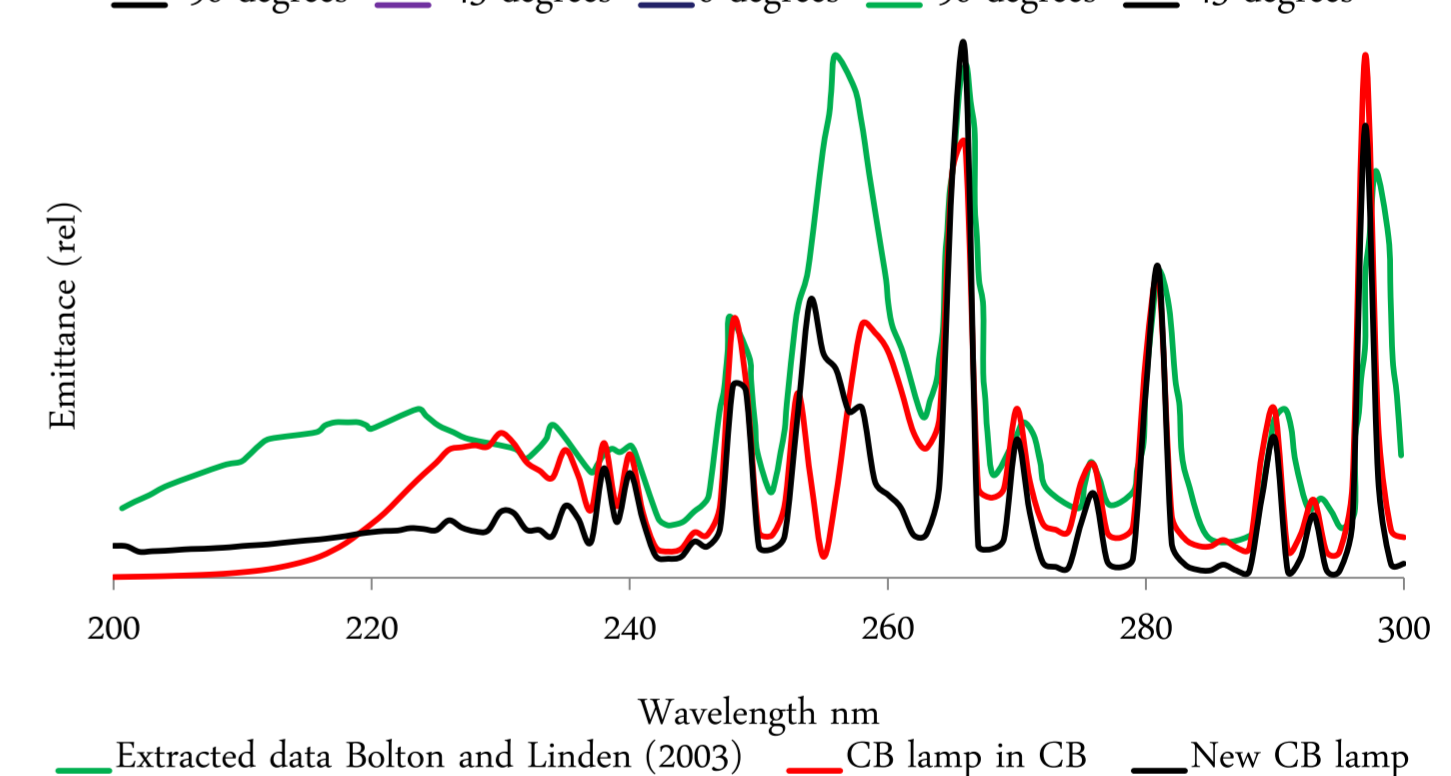


Fig 4; Spectral emittance of Collimated beam



## Future Work

A tunable light source has been constructed (see Fig 1) that is designed to provide:

- High resolution action spectrum data (expected 5nm bandwidth) from 200-300nm
- Investigation of the relevant importance of wavelengths in MS2 phage inactivation
- Investigation into a greater range of organisms' spectral sensitivity to MP UV.

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