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Comparison of different Far-UVC sources with regards to intensity stability, estimated anti-microbial efficiency and potential human hazard in comparison to a conventional UVC lamp

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INTRODUCTION & AIM

Background

- the strong antimicrobial impact of 254 nm mercury vapor UVC lamps – caused by there DNA/RNA destroying properties - has been known for a century [1]
- unfortunately, this UVC radiation also damages human cells
- the uprising Far-UVC sources – with peak emissions between 200 and 240 nm – promise strong disinfection without much harm to humans
- however, there are various Far-UVC sources that differ in their dangerous longer wavelength UVC emission and, subsequently, in their risk potential
- they might also exhibit changes in their emission intensity if they are in prolonged operation, e.g. to disinfect the air in waiting halls

Aim

- assess four far-UVC sources and a conventional Hg UVC lamp with regard to their risk to humans and antimicrobial impact by their spectral emissions and known sensitivities
- investigate lamp stability and potential drop in UVC intensity

METHOD

Source emission spectra

The emission spectra of these five (Far-) UVC sources were measured for about 100 h by a calibrated spectrometer CAS 140D from Instruments Systems (Munich, Germany):

- 222 nm KrCl lamp (20 W, filtered), type "UV222" of UVMedico (Aarhus, Denmark) with a KrCl 222 nm module of Ushio (Cypress, USA)
- 222 nm KrCl lamp (20 W, filtered), type "DF28B" of Conlustro (Sheridan, USA)
- 222 nm KrCl lamp (5 W, unfiltered), type "DF15B-B1" of France-UVC (Lévignac de Guyenne, France) in combination with a provided electrical converter and a lab power supply at a constant current of 1 A
- 236 nm Far-UVC LED (0.3 W, unfiltered), type "SF1 flat lens" of Silanna UV (Pinkenba, Australia) in combination with a lab power supply at a current of 40 mA
- 254 nm Hg lamp (6 W, unfiltered), type "3UV36" of Analytik Jena (Jena, Germany)

Assessment

- with the determined emissions spectra $E(\lambda)$ – normalized to 1 mW/cm² – the known sensitivity of *Bacillus subtillis* spores $A(\lambda)$ [2], the relative spectral effectiveness for the irradiation of eye and skin $S(\lambda)$ [3] – both as illustrated in Figure 1 - the relative antimicrobial efficacy $X_{antimic}$ and the hazard to human eyes and skin X_{hazard} of (Far-) UVC sources can be calculated:

$$X_{antimic} = \sum_{200\,nm}^{339\,nm} E(\lambda)\ x\ A(\lambda)\ x\ \Delta\lambda \qquad X_{hazard} = \sum_{200\,nm}^{400\,nm} E(\lambda)\ x\ S(\lambda)\ x\ \Delta\lambda$$

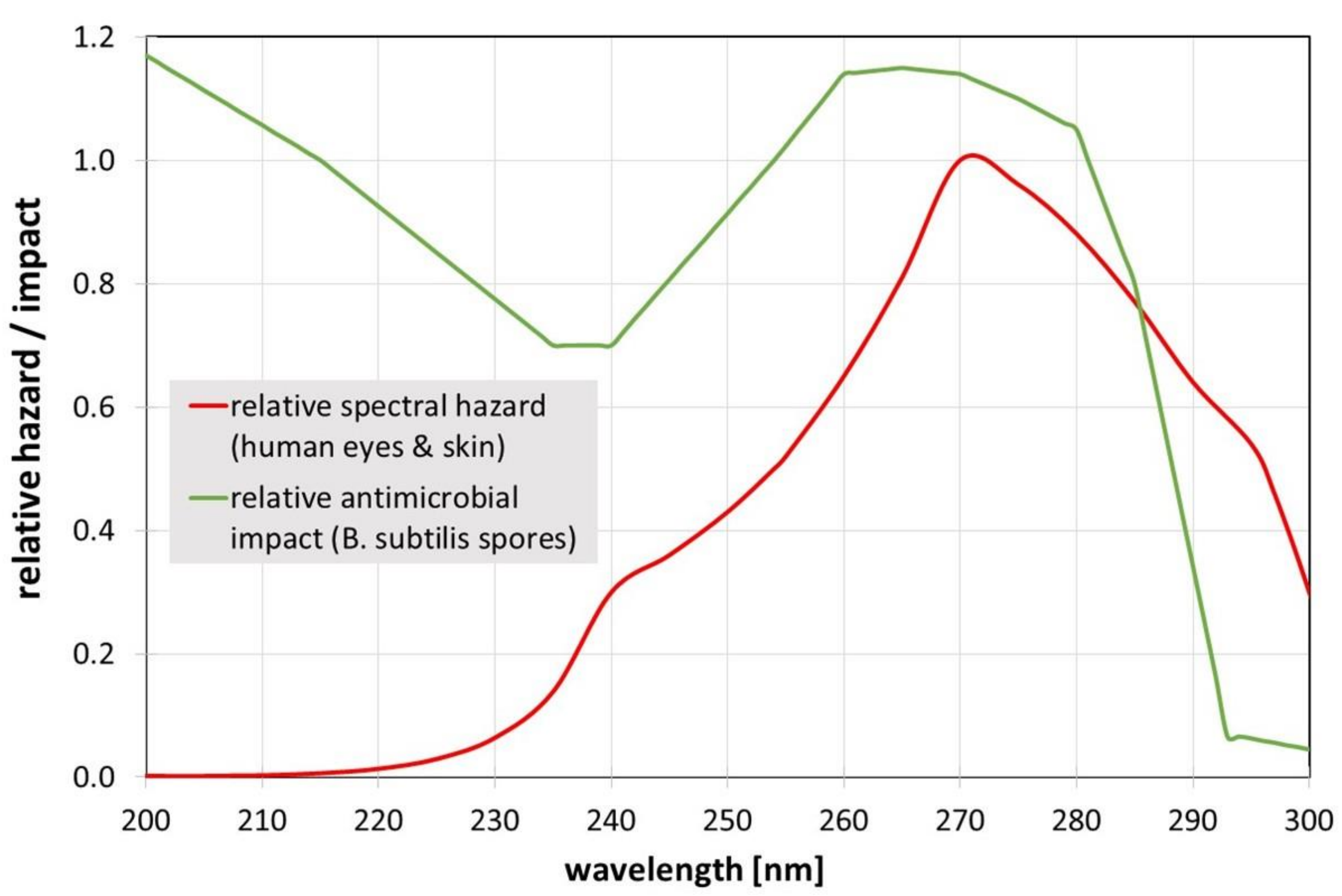

Figure 2: Spectrally resolved relative antimicrobial impact and potential hazards to human eyes and skin for the UV range 200 – 300 nm according to DIN 5031-10 and the ACGIH-TLVs [2,3].

RESULTS & DISCUSSION

Source emission spectra and assessment

- the normalized emission spectra can be found in Figure 2
- the intensity variations over a period of 100 h are given in Figure 3
- the relative antimicrobial effect (compared to the Hg lamp) and the relative hazard (compared to the filtered KrCl lamp of UVMedico/Ushio) are listed in Table 1.

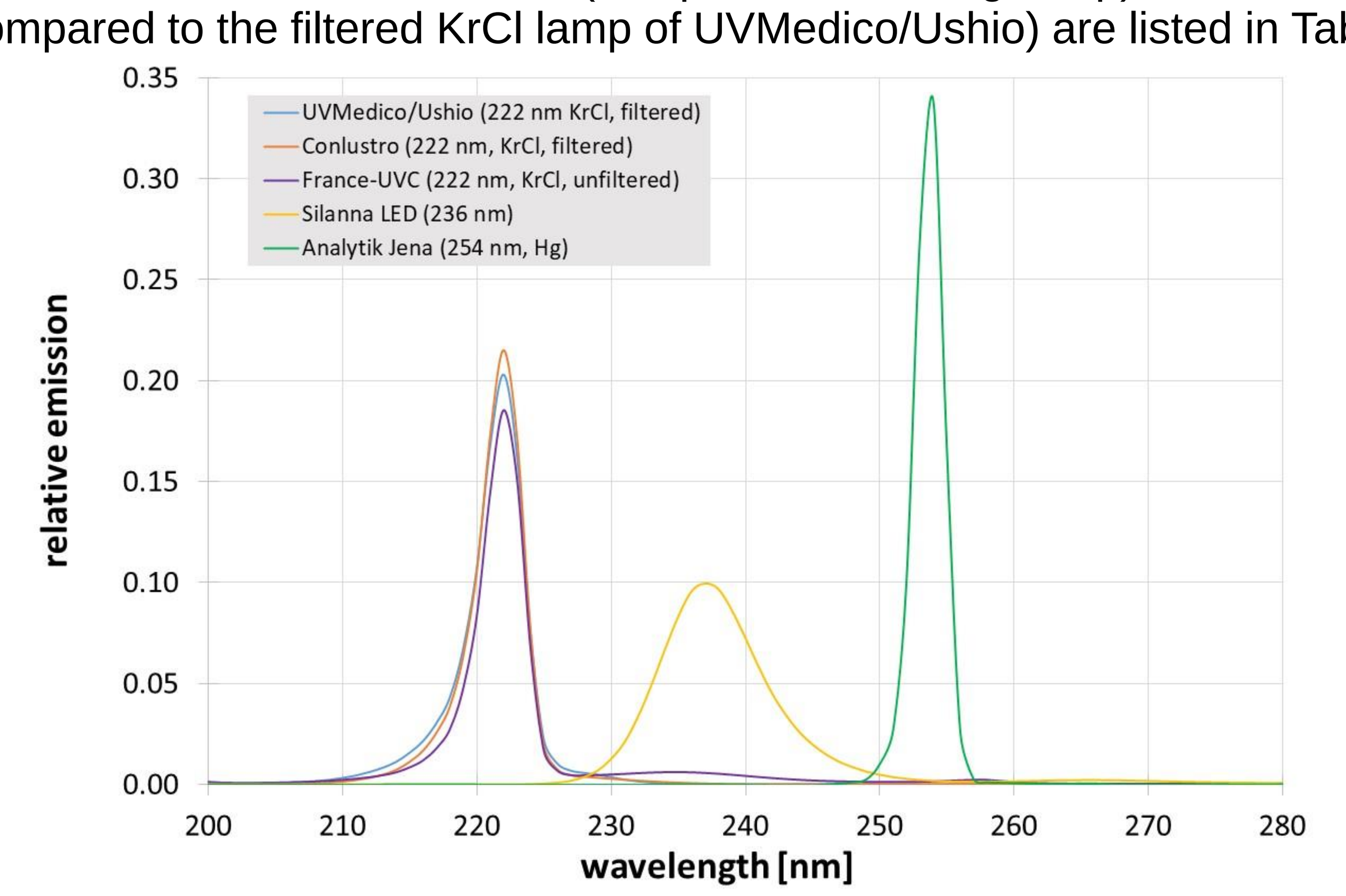

Figure 2. Spectral irradiances of different UVC sources, normalized to a UV irradiation of 1 mW/cm².

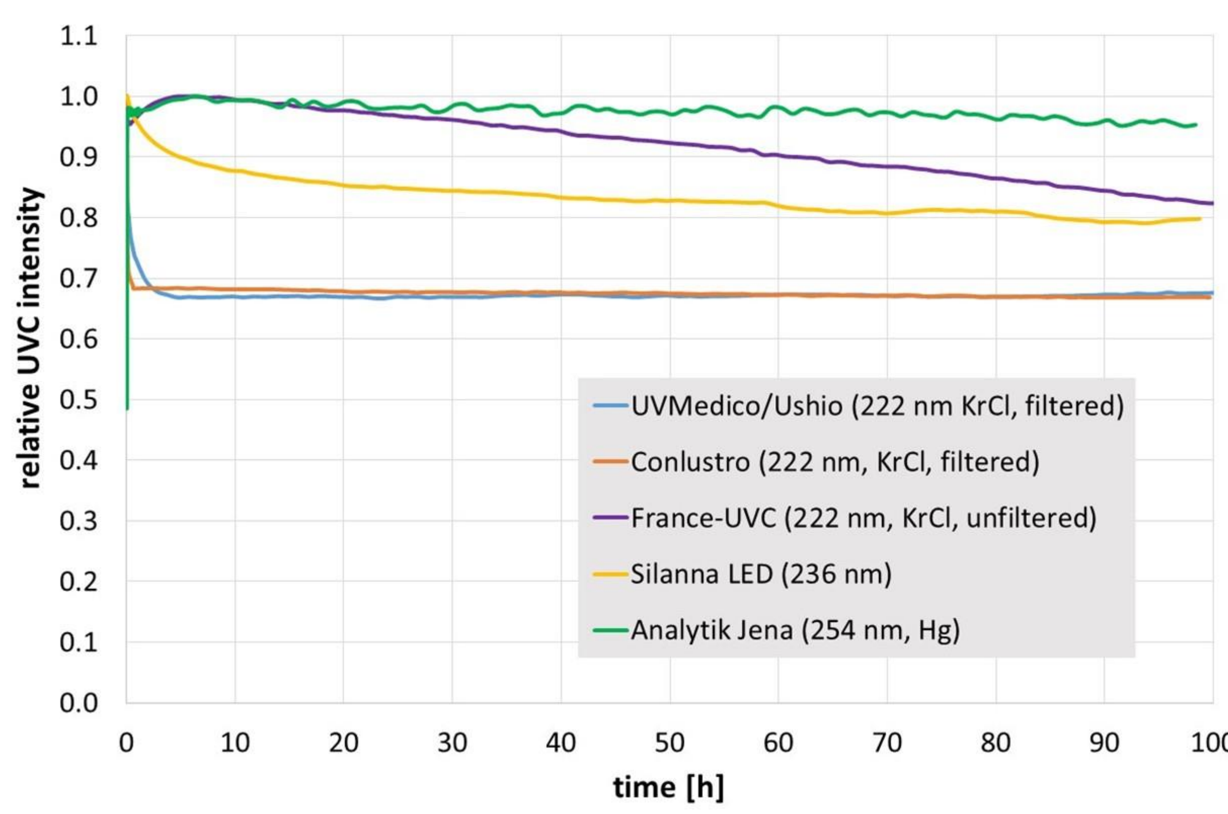

Figure 3: Time-dependent intensity variation of various UVC sources over a period of about 100 h.

Table 1: Calculated relative antimicrobial effect according to *B. subtilis* data [2] and hazard assessment for human eyes and skin based on ACGIH spectral effectiveness [3]. The values for antimicrobial efficacy and human exposure in brackets are scaled to the effect of the Hg lamp and the filtered KrCl lamp from UVMedico/Ushio, respectively.

	UVMedico/Ushio (222 nm KrCl, filtered)	**Conlustro** (222 nm KrCl, filtered)	**France-UVC** (222 nm, KrCl, unfiltered)	**Silanna LED** (236 nm)	**Analytik Jena** (254 nm, Hg)
antimicrobial impact (normalized to Analytik Jena lamp)	0.907 (0.96)	0.880 (0.93)	0.826 (0.87)	0.737 (0.78)	0.946 (1.0)
eye & skin hazard (normalized to filtered UVMedico/Ushio lamp)	0.019 (1.0)	0.022 (1.17)	0.055 (2.9)	0.247 (13)	0.475 (25)

CONCLUSION

- all UVC sources exhibit more or less the same relative antimicrobial impact
- the eye and skin hazard differ extremely – even between filtered and unfiltered KrCl lamps there is a factor of three
- the hazards posed by all Far-UVC sources are lower than for the Hg lamp
- the emission intensities of the filtered KrCl lamps are most stable after 30 min

⇒ So far, filtered KrCl lamps seem to be the best choice for a UVC source with a strong antimicrobial impact, low risk to humans and stable intensity over longer periods

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