

Comparison of two UV Systems for Terminal Disinfection of Patient Rooms Contaminated with MRSA, ESBL-producing *Klebsiella pneumoniae* and *Clostridium difficile*

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Background

Hospital acquired infections arising from *Clostridium difficile* (CD) infection, methicillin-resistant *Staphylococcus aureus* (MRSA) and *Klebsiella pneumoniae* (KP) are a major cause of morbidity in both hospital and community care in the UK and Europe. Patients may disseminate bacteria/spores into the clinical environment and can be acquired by a subsequent occupant if not effectively removed from proximal surfaces.

Physical decontamination (manual cleaning) of surfaces may reduce transmission but is labour intensive and subject to variability despite use of biocidal/sporicidal agents.

UV irradiation technologies may offer advantages over manual decontamination by increasing coverage and access to difficult-to-clean areas. As part of an infection-control programme, two UV-irradiation devices were introduced into a London teaching hospital and evaluated for disinfection efficacy.



Figure 1 The Surfacide® Helios™ whole-room disinfection UV-emitting lamp set-up in rooms in a "triangular" arrangement. The lamps use a laser-mapping system to measure the room size and determine the cycle duration. A control unit (tablet device) controls the system remotely from outside the room.



Figure 2a (left) The Hygiene Solutions Ultra-V™ whole-room disinfection UV-emitting lamp. **Figure 2b** (top right) The Hygiene Solutions UV-sensing device (Spectromes). **Figure 2c** (bottom right) Operating the Hygiene Solutions Ultra-V™ system from outside the room: the control-unit guides the operator and alerts when the disinfection cycle is complete.

Methods

Upon discharge of a patient from a single-isolation room (SIR) terminal disinfection (manual cleaning using a biocide) was requested under the standard hospital policy. Test bacteria ($\sim 10^5$ cfu MRSA, *K. pneumoniae*) or spores (10^4 cfu *C. difficile*) prepared in low soiling (0.03%BSA), heavy soiling (10%BSA) or synthetic faeces (*C. difficile* only) were inoculated onto 1cm² biological-indicator coupons (stainless-steel discs) and placed at various locations (1-Floor, 2-Under bed, 3-Footrail, 4-Headboard, 5-bedside table) in the room.

Enhanced cleaning/disinfection (UV-irradiation) of the SIR was performed using one of two devices:

Surfacide® Helios™: a triple-emitter system (UVC, $\lambda=254$ nm) arranged around the bed in triangular formation

Hygiene Solutions Ultra-V™, Hygiene Solutions: a single-emitter device (UVC, $\lambda=265$ nm) relocated intermittently as determined by sensors in room

Surface swabs (contact plates; 25cm² area) were taken from 14 environmental sites before and after terminal disinfection and after enhanced disinfection (UV-irradiation). Biological indicator coupons were assayed to quantify bacterial/spore numbers and compared against numbers obtained from a control array (non-exposed BI coupons).

Surfacide® Helios™ System uses three towers containing three UV-emitting bulbs (254nm) to access a 360° field of irradiation (figure 1). The system may be arranged to "direct" UV irradiation into a narrow field-of-view to allow targeted disinfection (e.g. of beds in a bay area). Operation requires the lamps to be placed in a "triangular" arrangement to cover all/as many surfaces. The Surfacide® Helios™ towers (lamps) have a built-in laser mapping system to scan the dimensions of the room and calculate the duration of the prescribed disinfection cycle.

Hygiene Solutions Ultra-V™ uses a single tower containing ten UV-emitting (268nm) bulbs to access a 360° field of irradiation (figure 2a). Operation of the system involves the use of 6 sensor-units, called Spectromes (figure 2b). Prior to decontamination, the Spectromes are positioned around the room e.g. corner-areas and areas requiring special attention. The Spectromes measure the dose of UV-energy received allowing the operator to deliver a minimum-dose of irradiation through targeted-cleaning.

Table 1. Efficacy of the Surfacide® Helios™ UV disinfection system against surface contamination in the patient environment (n=6)

#	Cleaning Phase	Environmental Surface Contamination (Aerobic colony counts) / 25cm ² - Surfacide® Helios™ UV					
		Pre-terminal clean		Pre-UV		Post-UV	
1	Floor corner	262	230-764	1760	1320-1944	6.5	5.75-13.3
2	Foot rail	30	27.3-69.3	0.5	0-1	0	0-0.25
3	Bed control panel	18	10-25.3	0	0-10	1.5	0-3.25
4a	Nurse call button (front)	45.5	24.8-129	10	0-23.25	0	0-0.25
4b	Nurse call button (back)	27.5	9.75-119	5.5	1.5-50.75	0	0-0
5	Bedside table	20.5	13.3-26	4.5	3-5.75	0	0-0
6	Chair arm	22	10.5-45.5	2.5	0.75-5	0.5	0-0
7	Bin lid	33	27-38.3	6.5	5.25-7.5	0	0-0.75
8	Inside door handle	10.5	2.25-20.3	0.5	0-2	0.5	0-1
9	Outside door handle	5.5	5-7.25	1.5	0.5-2.25	21.5	5.5-40
10	Toilet floor	340	230-663	504	412-1652	48.5	39.8-49.8
11	Toilet assist bar	1	0.25-5.5	0	0-1.5	0	0-0
12	Toilet flush	20.5	4.75-50.5	0	0-1.5	0	0-0
13	Toilet seat	36.5	8.5-90	1	1-1.75	0.5	0-2.5
14	Shower handle	36.5	10.5-67	1	0.25-4	1	0.25-1.75

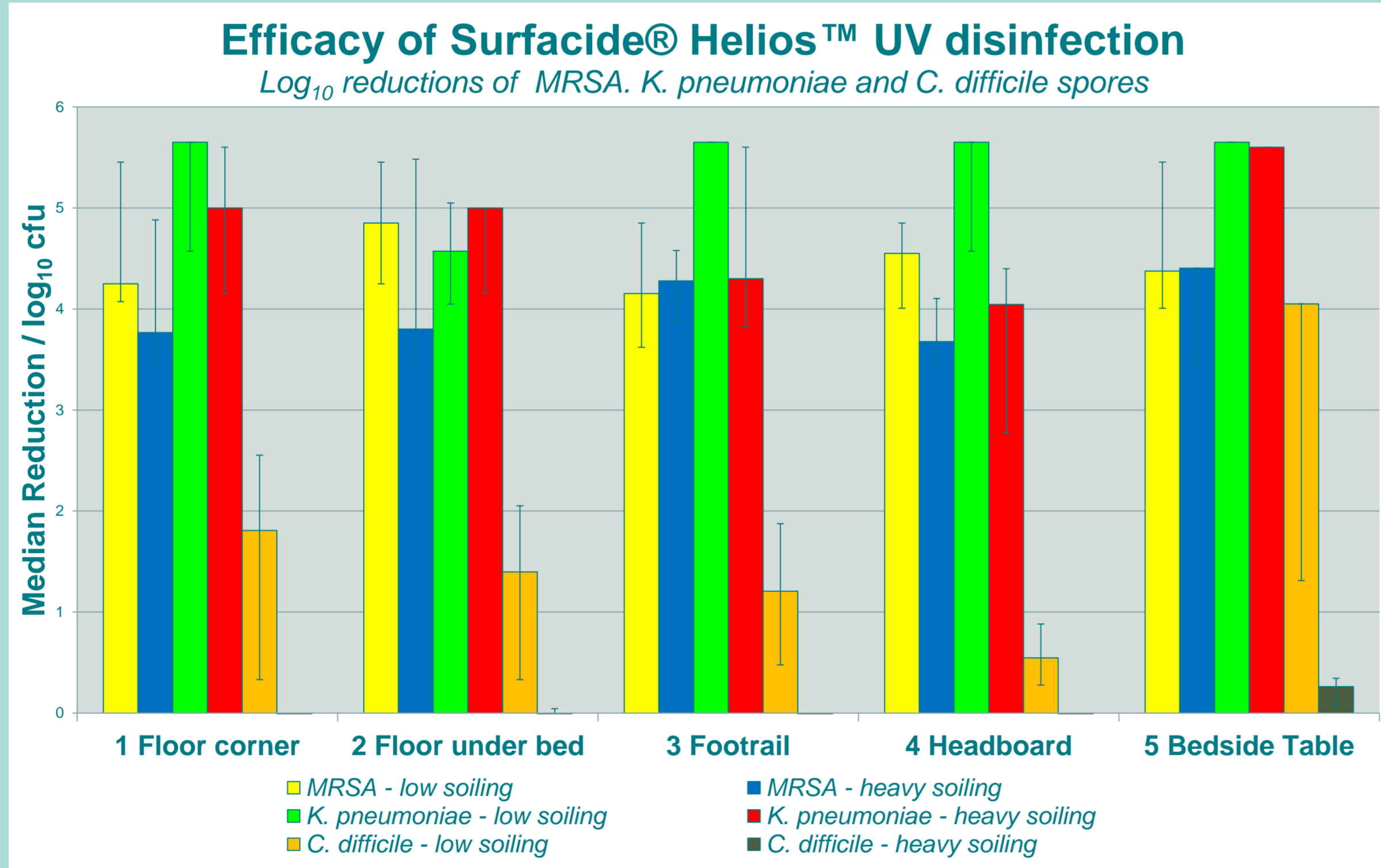


Figure 3. Efficacy of the Surfacide® Helios™ UV disinfection system evaluated using BI coupons inoculated with ~ 5 log₁₀ bacteria (MRSA, *K. pneumoniae*) or ~ 4 log₁₀ *C. difficile* spores. Median log₁₀ reductions shown (\pm IQR; n=9).

Table 2. Efficacy of the Hygiene Solutions Ultra-V™ UV disinfection system against surface contamination in the patient environment (n=6)

#	Cleaning Phase	Environmental Surface Contamination (Aerobic colony counts) / 25cm ² - Hygiene Solutions Ultra-V™ UV					
		Pre-terminal clean		Pre-UV		Post-UV	
1	Floor corner	233.5	81.25-442	736	600-800	16	6.5-27
2	Foot rail	51.5	34.75-67.5	8	3.5-14.75	0.5	0-1
3	Bed control panel	59	21.75-75.25	10	1-21.25	0	0-0.75
4a	Nurse call button (front)	82	49.25-180.75	0.5	0-7	0	0-1.5
4b	Nurse call button (back)	54	36-229.5	1	0.25-10	0	0-1.5
5	Bedside table	22	11-70	2	0-2	0	0-2
6	Chair arm	54.5	31.25-68	5	2.25-8.5	0	0-0
7	Bin lid	59	36.25-66	4.5	2.5-5.75	0	0-0.75
8	Inside door handle	17	8.5-30	2	1.25-2.75	0	0-0.75
9	Outside door handle	18.5	12-45.25	5	1-16.5	22	16.5-33.5
10	Toilet floor	420	177-780	768	552-1118	17	12.25-22.5
11	Toilet assist bar	4	0.5-8.25	0	0-6	0	0-0
12	Toilet flush	20.5	10-29.5	1.5	1-2.75	0	0-0
13	Toilet seat	44.5	16-70	5.5	1.5-10.25	0	0-0
14	Shower handle	62	18.5-105.5	0.5	0-1.75	0	0-0

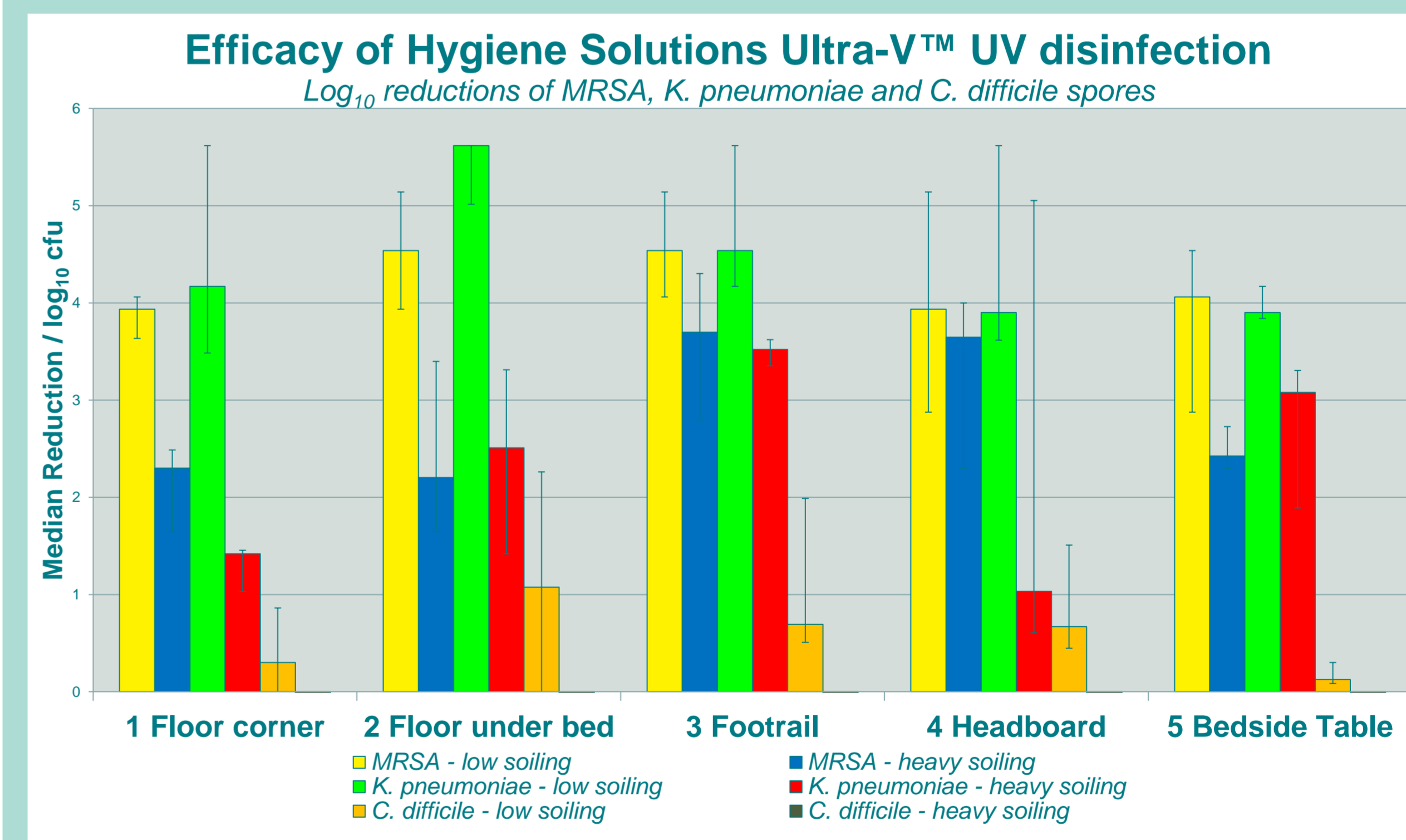


Figure 4 Efficacy of the Hygiene Solutions Ultra-V™ UV disinfection system evaluated using BI coupons inoculated with ~ 5 log₁₀ bacteria (MRSA, *K. pneumoniae*) or ~ 4 log₁₀ *C. difficile* spores. Median log₁₀ reductions shown (\pm IQR; n=9).

Results / Discussion

All rooms selected were of similar size and included a dedicated en-suite bathroom.

Terminal cleaning of the SIR and bathroom ranged between 95min \pm 35min (Surfacide® Helios™ study) and 81min \pm 34min (Ultra-V™ study). Additional time incurred by supplementing terminal disinfection with enhanced (UV) disinfection was similar between the two systems (Surfacide® Helios™; 35 \pm 14min, Ultra-V™; 36 \pm 6min) when completing a full cycle (as determined by each device) in the SIR and a further cycle in the bathroom.

Environmental contamination

All (14/14) environmental sites were contaminated before terminal disinfection in both arms of the study (Table 1 and 2). Contamination was highest on the floor areas of the SIR and patient en-suite bathroom also on high-frequency touch areas (foot rail, bed-control panel, nurse-call button, bedside table, chair arm). Terminal disinfection was ineffective in reducing contaminating numbers in up to 13/14 sites (93%) including near-patient surfaces. Enhanced disinfection eliminated contamination in 8/14 (57%) and 11/14 (79%) using the Surfacide® Helios™ and Ultra-V™ respectively.

Efficacy against biological indicator coupons

The Surfacide® Helios™ system demonstrated ~ 5 log₁₀ reductions in MRSA and KP regardless of soiling level from all areas of the SIR (locations 1-5). The Hygiene Solutions Ultra-V™ demonstrated ~ 4 -5log₁₀ reduction in MRSA and KP under low soiling and ~ 2 -4log₁₀ reduction with heavy soiling.

Approximately 1-2log₁₀ reductions in CD with low soiling was achieved on floor surfaces, difficult-to-access areas (location 1-2) and high-frequency-touch sites (location 3-4) but less effective (0-0.3log₁₀ reduction) when heavy soil (synthetic faeces) was present. However, the Surfacide® Helios™ system effectively reduced >4 log₁₀ CD from the bedside table.

Increases in contamination on floors post terminal cleaning resulted in a review of manual cleaning protocols and biocide application to assure adequate reductions in numbers.

Conclusion

Enhanced disinfection using UV light is effective against MRSA and *K. pneumoniae* and can reduce contamination from surfaces missed during terminal cleaning. Despite variations in reduction with high inoculum doses on BI coupons, both systems achieved reductions in bacterial numbers similar to contamination levels observed in the patient environment during the study.

C. difficile spores proved difficult to reduce. UV cycles should therefore be increased in rooms exposed to or at risk of *C. difficile* contamination.

The positioning of the devices used in our study was effective in preventing shadowed areas. In-house validation studies should be considered on implementation of UV disinfection systems to assure correct positioning and cycle-duration. Feedback from the evaluations in this study has facilitated future improvement of both systems tested.