Health Protection Scotland

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# Literature Review and Practice Recommendations: Existing and emerging technologies used for decontamination of the healthcare environment

# HINS Light

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# Contents

Topic....3
Background....3
Aim....4
Objectives....4
Research questions....5
Methodology....6
Search Strategy....6
Exclusion criteria....6
Screening....7
Critical appraisal....7
Results....8
Discussion....19
Conclusion....21
Recommendations for practice....23
Implications for research....23
Appendix 1: Medline Search....24
References....25

## Topic

The use of high-intensity narrow-spectrum (HINS) light for decontamination of the healthcare environment and reusable non-invasive patient care equipment.

## Background

There is strong scientific evidence that contaminated environmental surfaces contribute to the transmission of pathogens in healthcare settings.[1-4] As such, environmental decontamination has an important role to play in the prevention and control of healthcare associated infections.[1-4]

The National Infection Prevention and Control (IP&C) Manual[4] for NHSScotland currently outlines the following recommendations on agents for **routine environmental decontamination** within the Standard Infection Control Precautions (SICPs chapter 1), which are the basic measures intended to be applied by all staff, in all care settings, at all times, for all patients:

> *A fresh solution of general purpose neutral detergent in warm water is recommended for routine cleaning. This should be changed when dirty or at 15 minutes intervals or when changing tasks.*
>
> *Routine disinfection of the environment is not recommended. However, 1,000 ppm available chlorine should be used routinely on sanitary fittings*.[4]

The National IP&C Manual also makes recommendations on agents for environmental decontamination in the chapter outlining Transmission Based Precautions (TBPs), which are intended to be applied when caring for patients who are known to have or are suspected of having an infection.[4] The following recommendations are made in relation to **routine environmental decontamination** when applying TBPs:

> *Patient isolation/cohort rooms/area must be decontaminated **at least daily** using either:*
>
> - *a combined detergent/disinfectant solution at a dilution of 1,000 parts per million available chlorine (ppm available chlorine (av.cl.)); or*
> - *a general purpose neutral detergent in a solution of warm water followed by disinfection solution of 1,000 ppm av.cl.* [4]

In addition, the following recommendations are made in relation to **terminal cleaning** when applying TBPs:

*The room should be decontaminated using either:*

- *a combined detergent disinfectant solution at a dilution (1,000 ppm av.cl.); or*
- *a general purpose neutral detergent in a solution of warm water followed by disinfection solution of 1,000 ppm av.cl.*[4]

Chlorine releasing agents are recommended for decontamination of sanitary fittings and for environmental decontamination under TBPs based on substantial evidence of their effectiveness against pathogens of HAI significance including norovirus and *C. difficile*.[5]

However, several issues and problems associated with the use of chlorine releasing agents such as corrosion of equipment and furnishings, release of toxic gas and respiratory irritation, has encouraged interest in alternative methods of decontamination.[6] There are numerous other existing technologies such as steam cleaners, and a growing list of novel technologies becoming available for decontamination of the healthcare environment.[7-9] Currently, these technologies have not been sufficiently assessed to advocate their use for environmental decontamination in NHS Scotland. A review is required to assess the effectiveness of technologies of interest to the infection control community, to consider any practical and safety considerations related to them, and to explore the associated costs.

## Aim

To review the evidence for using high-intensity narrow-spectrum (HINS) light for decontamination of the healthcare environment and reusable non-invasive patient care equipment.

## Objectives

- To provide a generic description of HINS light, including the proposed or actual mechanism of action and the procedure for use.
- To assess the scientific evidence for effectiveness of HINS light.
- To explore practical and safety considerations related to the use of HINS light.
- To explore the costs associated with HINS light.

- To produce an evidence sheet for HINS light to assist the Environmental Decontamination Steering Group in making practical recommendations on the use of HINS light for NHSScotland.

## Research questions

The following research questions will be addressed for HINS light:

1. Is HINS light currently in use in UK healthcare settings?
2. What is the actual or proposed mechanism of action of HINS light?
3. What is the procedure for using HINS light?
4. What is the scientific evidence for effectiveness of HINS light for decontamination of the healthcare environment?
5. Are there any safety considerations associated with using HINS light in the healthcare setting?
6. Are there any practical or logistical considerations associated with using HINS light in the healthcare setting?
7. What costs are associated with using HINS light in the healthcare setting?
8. Has HINS light been assessed by the Rapid Review Panel?

# Methodology

## Search Strategy

The following databases and websites were searched to identify relevant academic and grey literature:

- MEDLINE
- CINAHL
- EMBASE
- NHS Evidence (http://www.evidence.nhs.uk/)
- Health Technology Assessment (HTA) Database (http://www.crd.york.ac.uk/CRDWeb/)
- Database of Abstracts of Reviews of Effects (DARE) (http://www.crd.york.ac.uk/CRDWeb/)
- National Patient Safety Agency (http://www.npsa.nhs.uk/)
- NICE (http://www.nice.org.uk/)
- MHRA (http://www.mhra.gov.uk/)
- Rapid Review Panel Reports Archive (http://www.hpa.org.uk/ProductsServices/MicrobiologyPathology/RapidReviewPanel/ReportsArchive/)

Search terms were developed and adapted to suit each database or website. Literature searches were run on 24/06/2014, 25/06/2014 and updated on 10/12/2015. During the course of this review it was established that the search terms used had not successfully found all the relevant articles available so additional searches were run on 22/02/2016. See Appendix 1 for an example search run in the Medline database.

## Exclusion criteria

Academic and grey literature was excluded from the review on the basis of the following exclusion criteria:

- Item was published before 2005
- Item was not in English
- Item does not concern HINS light (off topic)

- Item is an opinion piece or non-systematic review
- Item does not present evidence compatible with the McDonald-Arduino evidentiary hierarchy[10]
- Study does not have a comparison in the form of standard cleaning methods

  *N.B. If the study has used rigorous methodology and includes comparisons in the form of positive and negative controls or has been conducted as a before and after study it may be considered for inclusion. If these studies are included, then these limitations must be highlighted in the report.*

Manufacturer information was not subject to the exclusion criteria outlined above, as it was sought primarily for information about the procedure for using the technology in question.

## Screening

There was a two-stage process for screening the items returned from the literature searches. In the first stage, the title and abstract were screened against the exclusion criteria by the lead reviewer. Items that were not excluded at the screening stage progressed to the second screening stage. In the second stage of the screening process, the full text of remaining items was screened against the exclusion criteria by the lead reviewer. Items that were not excluded at the second screening stage were included in the review.

## Critical appraisal

Critical appraisal of the studies included in this review and considered judgement of the evidence was carried out by the lead reviewer using SIGN methodology.[11] The McDonald-Arduino evidentiary hierarchy[10] was used as the framework for assessing the evidence, and was integrated into the critical appraisal process.

## Results

The search found 113 articles. After the first stage of screening using the title and abstract this was reduced to 44 full text articles to read. After stage two screening there were twelve articles that fulfilled the inclusion criteria and were critically appraised for inclusion in this review. All of these were experimental studies classed as **level 3 evidence** (experimental or observational analytical studies). Of these, three took place in hospitals[12-14] and nine took place in laboratory settings.[15-23] The hospital based studies were before and after studies, using samples taken before and after the use of HINS light as controls for the samples taken while HINS light was being used.[12-14] The laboratory based studies all used control samples that were not exposed to HINS light.[15-23] None of the studies compared HINS light to other cleaning methods.

Two of the studies took place in USA[20;23] and the other ten took place in Scotland.[12-19;21;22] As the vast majority of the studies took place in Scotland, it would be reasonable to suggest the results would be applicable. It is worth noting that all the studies that took place in Scotland involved the same authors and took place at Strathclyde University. It is also worth noting that as HINS light is designed for continuous decontamination purposes it may be reasonable that none of the studies included comparisons to other cleaning methods.

The studies used a range of methodologies to investigate the effectiveness of HINS light with different **study aims** and organisms. There were three hospital based studies that investigated the use of HINS light for **environmental decontamination** in isolation rooms in a burns unit[12;13] and an ICU.[14] One of these studies compared the effects in inpatient and outpatient settings,[12] one compared the effects in occupied or unoccupied rooms using HINS light intermittently[13] and one sampled different sites in the room to investigate any spatial effects.[14] One laboratory based study tested the **safety** aspects of using 405nm light in the presence of patients in a healthcare setting using osteoblasts[16] (bone forming cells) to ascertain if the 405nm light had any detrimental effects on osteoblast cells. It would be reasonable to generalise from the three studies that took place in healthcare settings,[12-14] however it may not be reasonable to generalise from the laboratory based studies[15-23] as a controlled laboratory based setting may not be an accurate representation of real-world conditions.

The studies investigated the bactericidal effect on a number of different **organisms**. Four studies tested the effects of HINS light on *S. aureus* or MRSA[14-16;23] and two studies tested the effect of HINS light on food borne pathogens such as *Salmonella*, *Shigella*, *Listeria* and *Campylobacter*.[17;18] Two studies compared the effect of HINS light on Gram positive bacteria

versus Gram negative bacteria[16;19] and one study compared the effect of HINS light on bacteria that were either in liquid suspensions or on exposed surfaces.[17] One study compared the effect of HINS light on vegetative cells to **endospores** of *Bacillus* spp. and *C. difficile*[21] and one study investigated the effect of HINS light on *E. coli* **biofilms** on glass and acrylic surfaces and compared it to the effect of HINS light on biofilms produced by other organisms.[22] Although many of these organisms represent sources of infection in healthcare settings, it may not be reasonable to generalise the results to other healthcare associated pathogens as they may have different epidemiology and survivability of surfaces.

It is difficult to assess the potential impact of the use of HINS light as all the studies included in this review used environmental surface contamination either in a hospital or laboratory setting as outcome measures and it is not possible to quantify the link between environmental contamination and healthcare associated infections.

## Research Questions

### 1. Is HINS light currently in use in UK healthcare settings?

There is no mention of HINS light in the NHSScotland National Cleaning Services Specification,[24] the NHSScotland National Infection Prevention and Control Manual,[4] the HPS Standard Infection Control Precautions Literature Review of Routine Cleaning in the Environment in the Hospital Setting,[25] the Association of Healthcare Cleaning Professionals (AHCP) Revised Healthcare Cleaning Manual,[26] or the National Patient Safety Agency (NPSA) Revised Healthcare Cleaning Manual.[27]

### 2. What is the actual or proposed mechanism of action of HINS light?

High-intensity narrow-spectrum (HINS) light is composed of violet light from the visible spectrum with a wavelength of 405 nanometres (nm). HINS light is thought to inactivate bacteria by using light to stimulate endogenous intracellular organic compounds in bacterial cells called porphyrins which lead to generation of reactive oxygen.[16] This process is known as **photodynamic inactivation**. Laboratory studies have shown that a range of light wavelengths in the region of 400-425 nm can be used for bacterial inactivation, but optimal antimicrobial activity has been found at 405 nm. This peak in activity correlates with the absorption maximum of porphyrin molecules which react with oxygen or cell components when exposed to light at this wavelength causing oxidative damage to the cell membrane and microbial cell death.[13;17;20;22;28]

### Comparing UV light and HINS light

UV light and HINS light are found close to each other on the electromagnetic spectrum and have similar features but their modes of action are quite different. Although UV light is strongly germicidal it is dangerous to humans and the different wavelengths corresponding to UVA, UVB and UVC can cause a wide range of detrimental effects to human skin and eyes. Violet-blue wavelengths in the visible spectrum can also have harmful effects when used at high irradiance levels, however light at 405 nm is benign and if used at appropriate irradiance levels is both germicidal and safe for human exposure.[15;28]

## 3. What is the procedure for using HINS light?

The high-intensity narrow-spectrum light environmental decontamination system (HINS light EDS), used by Maclean *et al.*[14] in their 2013 study was a ceiling mounted lighting system developed to provide continuous disinfection of the air and all exposed surfaces in occupied clinical environments. Coyle *et al.*,[29] Bache *et al.*[12] and Maclean *et al.*[13]also used HINS light EDS as a ceiling mounted light source. Bache *et al.*[12] and Maclean *et al.*[13] describe their HINS light units as generating light from a matrix of light emitting diodes (LEDs) and emitting a narrow bandwidth of blue-violet light centred on a wavelength of 405 nm, with white LEDS incorporated into the system so that the resulting illumination was predominantly white. The dose of HINS light used is the product of irradiance (the rate at which solar power falls on a surface), measured in Watts per square metre, and the duration of exposure.

## 4. What is the scientific evidence for effectiveness of HINS light for decontamination of the healthcare environment?

As detailed in the protocol, the McDonald-Arduino evidentiary hierarchy was used as the framework for assessing the evidence, and has been integrated into the critical appraisal process.[30]

**Level V – Demonstration of reduced microbial pathogen acquisition (colonisation or infection) by patients via *non-outbreak* surveillance testing and clinical incidence:**

No evidence identified.

**Level IV – Demonstration of reduced microbial pathogen acquisition (colonisation or infection) by patients via *outbreak* surveillance testing and clinical incidence:**

No evidence identified.

**Level III – Demonstration of in-use bioburden reduction that may be clinically relevant:**

No evidence identified.

**Level II – Demonstration of in-use bioburden reduction effectiveness:**

Bache *et al.*[12] conducted a hospital based before and after study to assess whether use of a HINS light environmental decontamination system (EDS) had a significant effect on reducing the levels of environmental bacterial contamination in inpatient and outpatient settings. Environmental samples were taken before, during and after the use of HINS light with the before and after samples acting as controls for the period when HINS light was used. An isolation room housing a burns patient was used as the inpatient setting. The HINS lighting EDS was able to reduce environmental contamination levels by 27-75% on samples taken in the morning however the samples taken in the afternoon and evening didn't have the same level of effectiveness. The authors suggest this was most likely due to direct contamination by patients or staff at times when there was more activity in the room. The outpatient room was cleaner than the inpatient rooms to begin with, but significant reductions in environmental bioburden were still demonstrated with a 61% reduction in contamination. This study had some limitations, notably that the effect of HINS light was only examined for a relatively short period of time on two consecutive days and therefore it is not known whether leaving the system on for longer periods of time would continue to reduce overall bacterial contamination or if the contamination levels would plateau after a period of time.

Maclean *et al.*[13] also conducted a hospital based before and after study to assess the effect of a HINS light environmental decontamination system (EDS) for the reduction of environmental bacterial contamination in a hospital isolation room, similar to work by Bache *et al.*[12] This study also compared bacterial counts and presumptive *S. aureus* before, during and after the use of HINS light. There were three test scenarios used to test HINS light: an unoccupied room, an occupied room with HINS light operated intermittently for an extended period and an occupied room with HINS light being turned on and off. All three test scenarios showed that the use of HINS light led to a significant reduction in bacterial counts and when the exposure period was prolonged the bactericidal effect was even more pronounced. In the unoccupied room, bacterial contamination levels remained low in the sample period after the HINS-light EDS was switched off, whereas in the occupied room contamination levels returned to pre-treatment levels within two days after the HINS-lights EDS were switched off. The use of HINS-light EDS resulted in a mean reduction from 3.5 to 1.3 cfu/cm$^2$ for the total CFU count, an estimated mean reduction from 0.84 to 0.42 cfu/cm$^2$ for the confirmed *S.*

*aureus* count, and from 0.73 to 0.26 cfu/cm$^2$ for the MRSA count. In addition, the proportion of recovered isolates confirmed to be MRSA after HINS-light EDS exposure was significantly lower (62.5%) than before exposure (87.5%) which may indicate that MRSA strains are particularly susceptible to HINS-light.

Maclean *et al.*[14] conducted a hospital based before and after study to assess the efficacy of the HINS-light EDS for environmental decontamination of an occupied isolation room within the ICU in terms of the environmental staphylococcal bacterial levels and the levels of total bacterial contamination in the room. They also investigated the influence of the position of the HINS light on decontamination effect by assessing the levels of bacterial contamination at specific sampling sites around the room. Samples collected during the use of HINS light were compared to samples taken before and after the use of HINS light. The results demonstrated that use of HINS light significantly reduced both the total bacterial contamination and the levels of staphylococcal contamination and that these levels of contamination were higher in both the pre-and post HINS samples. Two studies were conducted to look at the difference in contamination levels before, during and after the use of HINS light-one showed a 67% reduction of contamination levels across all the sampled sites during use of the HINS light EDS and the other showed 38% reductions in contamination levels during the use of HINS light but this was not statistically significant. One study assessed the decontamination effect on surfaces directly below the HINS light EDS as well as on indirectly exposed surfaces on the other side of the room. The study found that although there were differences in the decontamination results between the two sides, there was nevertheless reduction of bacterial contamination with the use of the HINS-light EDS, and an increase after the system was turned off, on both sides of the room. This suggests that the installation positions of the HINS-light EDS units within a room may not be critical, and that killing of airborne bacteria contributes to the reductions in bacterial contamination levels.

**Level I – Laboratory demonstration of bioburden reduction efficacy:**

McDonald *et al.*[16] conducted a laboratory based experimental study to test the safety of HINS light for environmental disinfection in theatres during surgery by assessing the viability of osteoblasts in culture following exposure to HINS light at 405 nm and demonstrated that light intensities of up to 5 mW/cm$^3$ delivered over a period of 2 hours did not have a damaging effect, but osteoblast cell function was affected at doses higher than this. They also tested the bactericidal efficacy of HINS light on *Staphylococcus aureus* and *Staphylococcus epidermidis* and compared the bacterial kill rates to control cells that were not exposed to HINS light. They found that while exposure to 5 mW/cm$^3$ 405 nm HINS-light

for 1 hour was not detrimental to osteoblast cells, it was capable of a potent bactericidal effect on *S. aureus* and *S. epidermidis* and had kill rates of 98.1 % and 83.2 % respectively. They also compared the bactericidal effect of HINS light on selected Gram positive and Gram negative bacteria and found that >90% inactivation of Gram positive bacteria took 5-30 minutes, compared to 10-60minutes for Gram negative bacteria.

Murdoch *et al.*[17] conducted a laboratory based experimental study to investigate the effect of exposure to HINS light on a range of bacterial pathogens and also assessed its effectiveness at inactivating bacteria in liquid suspensions and on exposed surfaces. They found that Gram positive species were more susceptible to 405 nm light inactivation than Gram negative species which is in line with results from other studies. The bacteria were inactivated both in liquid suspension and when seeded onto exposed surfaces, but some of the bacteria were more resistant and needed higher doses (increased duration of exposure and/or increased irradiance) than the more susceptible bacteria. The most resistant bacterium in **liquid suspension** was *S. enterica*, which was inactivated by 3.5 $\log_{10}$ $CFUmL^{-1}$ at a dose of 288 J $cm^{-2}$, around 2.5 times the dose required for 5 $\log_{10}$ CFUmL−1 inactivation of the most susceptible bacterium *L. monocytogenes* (108 J $cm^{-2}$). *L. monocytogenes* was also the most susceptible organism when **seeded onto agar surfaces**, with 100% inactivation achieved with an average dose of 128 J $cm^{-2}$. The most resistant microorganism in the agar surface exposure experiments was *S. sonnei* with a 2.10 $\log_{10}$ CFU/plate (99.3%) reduction in bacterial numbers achieved at an average dose of 192 J $cm^{-2}$. The inactivation process was also shown to be dose dependent with higher intensity light sources able to inactivate bacteria in shorter time periods.

Murdoch *et al.*[18] conducted a laboratory based experimental study to investigate the effect of HINS light on *Campylobacter jejuni* and compared the sensitivity of *C. jejuni* to HINS light to the sensitivities of *Salmonella enteritidis* and *Escherichia coli* O157:H7. HINS light was shown to be highly bactericidal to *C. jejuni* and these bacteria were much more sensitive to 405 nm light than *S. enteritidis* and *E. coli* O157. The dose required to inactivate both *S. enteritidis* and *E. coli* O157 by 3 $\log_{10}$ $CFUml^{-1}$ and 5 $\log_{10}$ $CFUml^{-1}$ was 288 $Jcm^{-2}$ which was 18 times the dose required for a 5 $\log_{10}$ $CFUml^{-1}$ reduction to non detectable levels in *C. jejuni* (18 $Jcm^{-2}$).

Maclean *et al.*[15] conducted a laboratory based experimental study to investigate the bactericidal effect of HINS light on *S. aureus* and MRSA and to identify the region of the visible spectrum that is able to induce staphylococcal inactivation. The results demonstrated inactivation of *S. aureus* using 400–420nm wavelength blue light, with the most effective bactericidal activity at 405±5 nm, and wavelengths of longer than 430nm were found to

induce no effect on the viability of *S. aureus* cells. The peak of bactericidal activity at 405nm suggests that *S. aureus* cells were most susceptible to this specific wavelength. This is in line with results from other studies.

Maclean *et al.*[19] conducted a laboratory based experimental study to investigate the effect of HINS light on a range of bacterial pathogens and also compared the bactericidal effects on a selection of Gram positive and Gram negative bacteria. This study demonstrated that HINS light was effective at inactivating the bacteria tested and similar to other studies, showed that Gram positive bacteria typically needed a lower dose of light for inactivation than Gram negative bacteria. This is line with results from other studies.

Guffey *et al.*[20] conducted a laboratory based experimental study to evaluate the bactericidal effect of HINS light on *Mycobacterium smegmatis*. The results showed that HINS light was effective at limiting growth of *M. smegmatis*, however the dose required to achieve this effect was higher than for many other organisms. The authors suggest that this increased resistance to HINS light may be due to mycobacterial cell walls which contain compounds such as peptidoglycan, arabinogalactan, and mycolic acids which are known to confer resistance to desiccation.

Maclean *et al.*[21] conducted a laboratory based experimental study to investigate the effect of HINS light on vegetative cells and endospores of *Bacillus cereus, Bacillus megaterium*, *Bacillus subtilis* and *C. difficile*. **Vegetative cells** of *B. cereus* and *C. difficile* were readily inactivated by exposure to high-intensity 405 nm light, although different applied doses were required. *B. cereus* was the more resilient of the two organisms, with more than double the dose required to achieve a similar log reduction to that of *C. difficile*. *S. aureus* vegetative cells were also used in the study as a comparative non spore former, and it was found that *S. aureus* was more susceptible to inactivation using 405 nm light than *B. cereus*, but less susceptible than the vegetative cells of *C. difficile*. Results demonstrated that *C. difficile* was highly susceptible to 405 nm light inactivation and given the proposed mechanism of action, this is likely to be due to this organism being an obligate anaerobe, giving it increased sensitivity to oxidative damage. Reductions in *B. cereus* **endospores** needed 16 times the HINS light dose that was required for a similar reduction in *B. cereus* vegetative cells. Similarly, *C. difficile* endospores needed a dose of HINS light that was approximately 48 times the dose required to achieve a similar reduction in vegetative cells. This large difference in the applied doses emphasises the significant difference in susceptibility between spores and vegetative bacterial cells.

McKenzie *et al.* [22] conducted a laboratory based experimental study to investigate the bactericidal effect of HINS light on *E. coli* **biofilms** of varying maturity, generated on glass

and acrylic surfaces. The study also investigated the effect of HINS light on biofilms of other bacteria including *P. aeruginosa, S. aureus* and *L. monocytogenes*. Results from this study demonstrate successful inactivation of biofilms on both glass and acrylic surfaces, and that the bactericidal effect was observed with both juvenile and mature biofilm populations. Overall, results showed that successful inactivation was achieved with *E. coli* biofilms generated on both glass and acrylic, with the general trend demonstrating that the more densely populated the biofilm, the greater the time (and consequently, the greater the dose) required for inactivation. Biofilms generated on **acrylic** surfaces over a 24 hour time period required increased exposure time for complete inactivation when compared with those on **glass** surfaces, despite having significantly lower starting bacterial populations. Successful inactivation of bacterial biofilms on the underside of the glass and acrylic surfaces was also shown, demonstrating the ability of HINS light to be transmitted through these transparent materials while maintaining its antimicrobial activity.

Guffey and Wilborn[23] conducted a laboratory based experimental study to determine the bactericidal effect of 405 and 470 nm light on *S. aureus*, *P. aeruginosa* and *Propionibacterium acnes*. 405 nm light had a dose dependant bactericidal effect on *P. aeruginosa* and *S. aureus* with reductions of 96.5% and 62% respectively. However, 405 nm was not bactericidal when used on *Propionibacterium acnes* and in fact had a stimulatory effect on growth. The dose of 405 nm light used appears to be critical. *P. aeruginosa* growth was negatively impacted at all doses, but the bactericidal effect peaked at 10 $Jcm^{-2}$. *S. aureus* needed a higher dose for a similar rate of bacterial kill; 15 $Jcm^{-2}$ for a 90% kill rate, compared to 5 $Jcm^{-2}$ needed for a similar effect in *P. aeruginosa*.

## 5. Are there any safety considerations associated with using HINS light in the healthcare setting?

Chlorine releasing agents are considered the cheapest and easiest environmental disinfection method. However, they have some limitations such as the release of irritating vapours and toxic gases which may affect the eyes and respiratory tracts of healthcare workers at high concentrations (e.g. 10,000ppm available chlorine) and for this reason personal protective equipment (PPE) is recommended. Hypochlorite based products can be corrosive to various materials. In addition, the disinfection process must be performed manually-which can be time consuming and the quality of disinfection depends on the staff performing disinfection. This has led to an interest in alternative methods of decontamination.[6;31;32]

HINS light with a wavelength of 405 nm has a **lower germicidal efficiency than UV light**, however this may be outweighed by the safety of HINS light to humans in sharp contrast to UV light which has well recognised risks of eye damage and skin cancer associated with exposure. HINS light is part of the visible light spectrum and despite being capable of inactivating a range of bacteria is also considered to pose a negligible threat to human health.[15;16]

405 nm is well below the wavelengths that have an impact on human health and other studies have shown that mammalian cells such as osteoblasts were considerably **more resistant** to HINS light than bacterial cells and could be exposed to this light for prolonged periods of time with no loss of cell viability. It is suggested that the increased resistance of mammalian cells to HINS light could be the result of having developed advanced systems for coping with oxidative damage compared to bacterial cells.[28]

As HINS light uses a wavelength of light that is safe for humans it can be used for **continuous** disinfection in the presence of patients and staff, allowing environmental cleanliness to be maintained for longer periods of time.[12;19;33]

**Safety analysis** of the complete wavelength emission spectrum of the light from the HINS-light EDS used by Maclean *et al.*[13] was conducted with reference to relevant international guidelines, and confirmed the safety of the HINS-light EDS source for clinical use.[13]

## 6. Are there any practical or logistical considerations associated with using HINS light in the healthcare setting?

The high-intensity narrow-spectrum light environmental decontamination system (HINS-light EDS) is a ceiling-mounted lighting unit, which allows continuous decontamination of the clinical environment, killing bacteria through photodynamic inactivation while being safe to humans. The HINS light system is designed to be operated continuously, providing environmental disinfection during daylight hours and as it does not impact on patient or staff safety it does not lead to any disruption to day-to-day hospital procedures or patient care.[12;28] This is in sharp contrast to many other cleaning technologies such as hydrogen peroxide vapour which are restricted for use in unoccupied, sealed rooms, resulting in rooms being out-of-commission for periods of time, which is both costly and undesirable in busy areas.[12;14]

Bache *et al.* used HINS light units that were connected to **mains electricity** and simply switched on and off at the wall.[12] The HINS light system uses light emitting diode (**LED**) based technology which is increasingly being used for lighting purposes due to lower energy

requirements, longer operational use and lower maintenance than traditional incandescent lighting or fluorescent lighting.[28;34]

As HINS light has a violet-blue hue, to avoid any impact on patient and staff comfort levels the HINS light EDS have **white LEDs** incorporated into the system for overhead lighting to ensure that illumination output is predominantly white and blends in with standard room lighting. It is important to be aware of the possible effects on medical procedures that involve colour perception however Maclean *et al.*[28] note that they had not encountered any such issues in their trials.

In the hospital based trials that have taken place,[12-14] the authors state that the HINS light unit was designed to be **easily retrofitted** into the ceiling in place of a ceiling tile and installed units have remained fully operational and maintenance free over the trial period which now extends to several years.[28] As HINS light uses visible light wavelengths there is unlikely to be any impact on materials and equipment unlike UV light which can cause degradation of equipment.[14]

The HINS light units are reported to be efficient, **simple** to run, unobtrusive, and are neither dependent on staff compliance nor require any additional staff time to implement. Minimal staff training was required as the system can be automatically operated and there was no disruption of the normal hospital routine.[12;28]

Some authors state that HINS light can be used to clean hard-to-reach places in rooms or areas where equipment make routine cleaning difficult,[14;28] whilst others are clear that HINS light is designed to be used in addition to routine cleaning rather than instead of it.[12] However it can be used continuously in areas which can be lit all day. Another limitation is that the high doses needed for HINS light to be sporicidal mean that it would need to be used in conjunction with other cleaning methods.[28]

## 7. What costs are associated with using HINS light in the healthcare setting?

The HINS-light system uses LED technology and this means it has the same advantages of LED lighting which are increasingly being used due to their lower energy requirements, longer operational use and lower maintenance. In the hospital based trials that have taken place,[12-14] the authors state that the HINS light unit was designed to be easily retrofitted into the ceiling in place of a ceiling tile and installed units have remained fully operational and maintenance free over the trial period which now extends to several years.[28] The lights should however, be regularly checked to ensure they are still emitting light at the appropriate doses and that all the LEDs are fully functioning. These factors are all associated with

reduced cost implications, although none of the studies elaborate on the costs of using HINS light in the healthcare setting.

## 8. Has HINS light been assessed by the Rapid Review Panel?

The Rapid Review Panel (RRP) is a panel of UK experts established by the Department of Health to review technologies with potential to help in the prevention and control of HAI.[35] To date no HINS light products have been assessed by the Rapid Review Panel.

## Discussion

None of the studies identified in this review compared the effectiveness of HINS light with other cleaning methods, e.g. hypochlorite. While this means that recommendations cannot be made to suggest whether HINS light is as effective/more effective/less effective than standard cleaning methods, it is also possible that such comparisons would not be useful as HINS light is designed for use in a different way to standard cleaning methods. As HINS light EDS involves the use of lights to provide continuous decontamination in healthcare settings in the presence of patients that may be in operating theatres or have open wounds or burns, it seems appropriate to use samples collected before and after the use of HINS light as comparisons for environmental samples collected during the use of HINS light.

There is evidence from three hospital based before and after studies (level 3 evidence) that HINS light was *effective* at reducing the levels of **environmental decontamination** in healthcare settings that included an isolation room in a burns unit[12;13] and an ICU.[14] One of the studies compared the effects in inpatient and outpatient settings[12] and found that the outpatient room was cleaner than the inpatient rooms to begin with, but significant reductions in environmental bioburden were still demonstrated. One of these studies showed that unoccupied rooms retained low levels of bacterial contamination even after HINS light was turned off, whereas in the occupied rooms the levels returned to what they were before the use of HINS light. In addition, if the exposure period was prolonged the bactericidal effect was shown to be even more pronounced.[13]

There is evidence from one hospital based before and after study (**level 3 evidence**) that although there was a *reduction* in bacterial contamination across the room with the use of HINS light, there was a greater effect in areas closer to the HINS light. However the reduction seen even in areas further from the HINS light indicate that the **installation position** of the HINS light units within a room may not be critical, and that killing of airborne bacteria contributed to the reductions in bacterial contamination levels.[14]

There is evidence from one laboratory based experimental study (**level 3 evidence**) that tested the **safety** aspects of using 405 nm light in the presence of patients in a healthcare setting by assessing the viability of osteoblasts in culture following exposure to HINS light and demonstrated that light intensities of up to 5 $mW/cm^2$ delivered over a period of 2 hours did not have a damaging effect on the osteoblasts but had a potent bactericidal effect on *S. aureus* and *S. epidermidis*.[16]

There is evidence from several laboratory based experimental studies (**level 3 evidence**) that HINS light was able to *inactivate* a range of **organisms** including *Staphylococcus*

*aureus*,[14-16;22;23] MRSA,[15] *Staphylococcus epidermidis*,[16] *Pseudomonas aeruginosa*,[23] *Propionibacterium acnes*,[23] *Mycobacterium* terrae,[12] *Mycobacterium smegmatis*,[20] *Clostridium difficile*,[21] *Salmonella* enteric,[12] *Salmonella enteritidis*,[18] *Shigella sonnei*,[17;23] *Listeria monocytogenes*,[23] *Campylobacter jejuni*,[18] *Escherichia coli* O157:H7[18;2212] and *Bacillus* spp.[21] Some of these organisms are commonly linked to healthcare associated infections and others are common food borne pathogens. The ability of HINS light to inactivate these bacteria could lead to potential use in healthcare and food industry settings.

There is evidence from three laboratory based experimental studies (**level 3 evidence**) that **Gram positive** species were *more susceptible* to HINS light inactivation than **Gram negative** species.[16;17;19]

There is evidence from one laboratory based experimental study (**level 3 evidence**) that although vegetative bacterial cells and **endospores** are both inactivated by HINS light, there is a significant difference in the doses required for inactivation with vegetative bacterial cells being much more susceptible to HINS light.[21]

There is evidence from one laboratory based experimental study (**level 3 evidence**) that HINS light was able to *inactivate* bacterial **biofilms** on glass and acrylic surfaces and also inactive biofilms on the underside of the surfaces, demonstrating the ability of HINS light to be transmitted through these transparent materials while maintaining its antimicrobial activity.[22]

There is evidence from one laboratory based experimental study (**level 3 evidence**) that HINS light was *effective* at inactivating bacteria in **liquid suspensions** and on **exposed surfaces**.[17]

## Conclusion

The limited low level evidence on this topic (**all level 3**) assessing the effectiveness of HINS light may reflect the fact that it is challenging to undertake well designed studies to explore the effectiveness of cleaning methodologies in the healthcare setting due to practical considerations. It may also reflect the fact that environmental decontamination in healthcare has not been considered a priority area for research. All of the studies included in the review are subject to methodological limitations to a greater or lesser extent, which limit the conclusions that can be drawn from them. Many of the outcomes measured in the studies included in this review are of limited use as they only demonstrate reduced bioburden in-use or in a laboratory setting which is less useful than demonstrating reduced infections or clinical incidence. However, such studies would also probably be more costly and difficult to conduct.

All the studies included in this review demonstrated the **effectiveness of HINS light** albeit using different methods, aims, doses of light and target organisms. The hospital based studies demonstrated **reductions in environmental contamination** associated with the use of HINS light but these are of limited use as it is not possible to quantify the link between environmental contamination and healthcare associated infections. However, these studies used HINS light environmental decontamination systems in the form of continuous LED lighting which would appear to be practical for many settings, especially as the rates of contamination remained low even after the HINS light was turned off. One hospital based study also tested the environmental contamination levels to see if there was a greater effect in areas closer to the light and found that although this was the case, bacterial reductions were seen even in areas further away from the light source indicating that killing airborne bacteria contributed to the reduction in bacterial contamination levels.

Although only one laboratory based study tested the germicidal efficacy of HINS light whilst also assessing the **safety** to humans using osteoblast cells in a laboratory setting, all the studies state that exposure to HINS light at 405 nm is safe for humans. Three laboratory based studies showed that the **Gram positive** bacteria they tested were *more susceptible* to HINS light inactivation than **Gram negative** bacteria they tested. One laboratory based study showed that although vegetative bacterial cells and **endospores** are both inactivated by HINS light, there is a significant difference in the doses required for inactivation with *vegetative bacterial cells being much more susceptible* to HINS light. One laboratory based study showed that HINS light was able to inactivate bacterial **biofilms** on glass and acrylic surfaces and also inactive biofilms on the underside of the surfaces, demonstrating the

ability of HINS light to transmit through these transparent materials while maintaining its antimicrobial activity. One laboratory based study showed that HINS light was effective at inactivating bacteria in liquid **suspensions** and on exposed **surfaces**.

The introduction of any novel decontamination technology should be used as part of a coordinated and structured infection control intervention and it is essential that recommendations by the local infection control team are followed. There may be circumstances where it is appropriate to use alternative decontamination technologies to supplement but not replace standard cleaning and disinfection methods, such as fumigation of a ward following an outbreak.[36] It is important that HINS-light EDS is not used to replace standard cleaning methods and that it is used in addition to standard infection control methods.[12]

As the costs involved in the use of HINS light decontamination systems were not discussed in any of the studies included in this review it would be helpful to know more about the cost implications before deciding whether it would be feasible for use in a healthcare setting. Whilst there is some evidence demonstrating the effectiveness of HINS light at 405 nm, there have been insufficient studies to assess practical considerations and support the use of HINS light decontamination systems in healthcare settings.

## Recommendations for practice

This review makes the following recommendations based on an assessment of the extant scientific literature on HINS light.

If NHS boards use HINS light products for decontamination of the healthcare environment and patient care equipment, the following must be considered:

- HINS light systems should only be used as a supplementary method to enhance routine environmental cleaning or disinfection. It should not be used to replace cleaning methods.
  **(Grade D recommendation)**
- Sodium hypochlorite cleans will still be required for decontamination of patient areas where infection risks are known or suspected (i.e. isolation/terminal cleans) when a HINS light system is in place.
  **(Grade D recommendation)**
- HINS light systems should be placed in an area of the room which directly reflects onto the patient area.
  **(Grade D recommendation)**
- HINS light systems should be included as part of a planned programme of maintenance to ensure optimal functioning.
  **(Good Practice Point)**

## Implications for research

This review identified some gaps in the literature in relation to HINS light. Although there were studies demonstrating a reduction in environmental contamination levels it would be useful to investigate the impact of HINS light on colonisation and infection in patients in a healthcare setting. However studies such as this would be harder to conduct and this may explain the paucity of evidence in this field.[12] There is insufficient data on the cost of implementing these products to enable cost-benefit analyses to be undertaken to establish the feasibility of using HINS light environmental decontamination systems.

# Appendix 1: Medline Search

Ovid MEDLINE(R) 1946 to present with daily update

AND

Ovid MEDLINE(R) In-process & other non-indexed citations

## Search dates

24/06/2014, 25/06/2014 and 10/12/2015

| 1 (all "OR") |
| --- |
| HINS.mp<br><br>High Intensity Narrow Spectrum light.mp |

**Limits**

English language

Publication Year 2005-current

Results: 31

## Additional search

22/02/2016

| 1 (all "OR") |
| --- |
| 405nm<br><br>405 nano* |

**Limits**

English language

Publication Year 2005-current

Results: 66

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