

New developments in environmental cleaning and disinfection

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Objective

- To present questions that highlight some recent developments in environmental cleaning and disinfection

Commonly used disinfectants

Active compounds	Contact time MRSA/VRE (min)	<i>Candida auris</i>	Sporicidal
Quaternary ammonium	3-10	No*	No
Quaternary ammonium + alcohol	1-5	No*	No
Hydrogen peroxide	.5-1	Yes	No**
Peracetic acid	1-5	Yes	Yes
Sodium hypochlorite (bleach)	1-5	Yes	Yes

*Some products are effective (EPA List P)

**A 4% hydrogen peroxide product is sporicidal

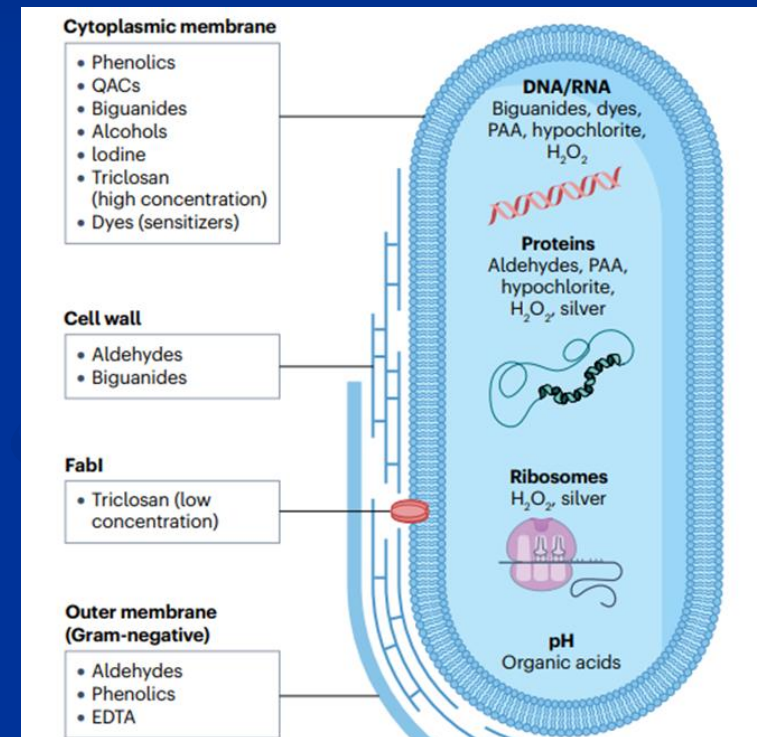
Question 1. Emergence of resistance is a concern for which disinfectant(s)?

- A. Chlorine-releasing disinfectants
 - Sodium hypochlorite (bleach)
 - NaDCC (sodium dichloroisocyanurate) – tablets
- B. Quaternary ammonium compounds
- C. Hydrogen peroxide
- D. None of the above
- E. All the above

Clinically relevant resistance to disinfectants is uncommon

- Commonly used germicides effective against antibiotic-resistant bacteria¹
- No strong evidence that reduced susceptibility is a major clinical problem²
- Inappropriate usage may potentially lead to resistance³

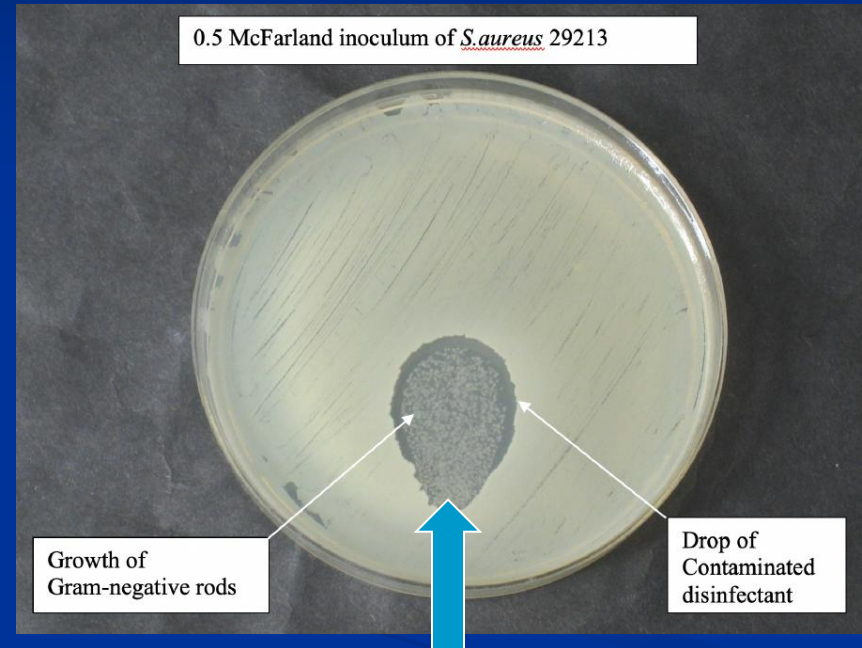
Mechanisms of action



1. Kanamori H. Germicidal Activity against Carbapenem/Colistin-Resistant Enterobacteriaceae Using a Quantitative Carrier Test Method. *Antimicrob Agents Chemother* 2018;62:e00318-18; 2. Harbarth S. Is reduced susceptibility to disinfectants and antiseptics a risk in healthcare settings? A point/counterpoint review. *J Hosp Infect* 2014; 3. Maillard JY. Disinfectants and antiseptics: mechanisms of action and resistance. *Nat Rev Micro* 2024.

Disinfectant used incorrectly: contamination of a quaternary ammonium disinfectant

- Large numbers of gram-negative bacteria recovered after cleaning
- Disinfectant bucket used for months without emptying or drying
- Contaminated with quat resistant bacteria



Contaminating strain of *S. marcescens* growing within zone of disinfectant inhibition

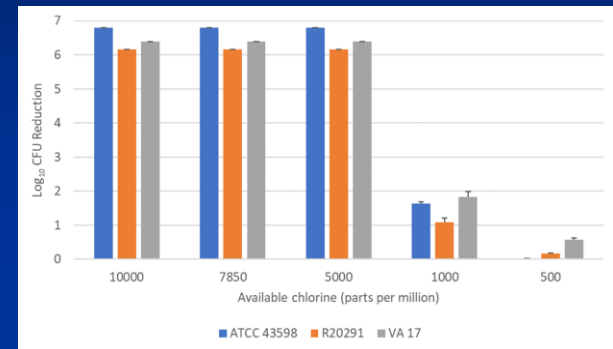
Bleach is no more effective
than water at killing off
common superbug, scientists
have found!!!!

Ahmed H, Joshi LT. *C difficile* spores tolerate disinfection with sodium hypochlorite disinfectant and remain viable within surgical scrubs and gown fabrics. Microbiology 2023; Malyshev D. Hypervirulent R20291 *C difficile* spores show disinfection resilience to sodium hypochlorite despite structural changes. BMC Microbiol 2023; Joshi LT. The effect of hospital biocide sodium dichloroisocyanurate on the viability and properties of *C difficile* spores. Lett Appl Microbiol 2017.

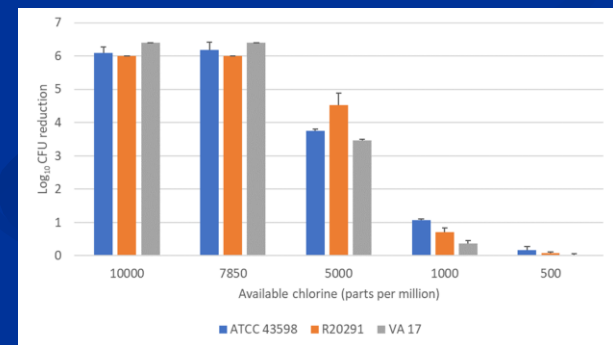
Bleach still works: A sodium hypochlorite product is effective against *C difficile*

- Recommended:
 - 7800 ppm
 - 3-minute contact time
- Minimal reduction if insufficient contact time (1 minute) or low concentration (500 or 1000 ppm)

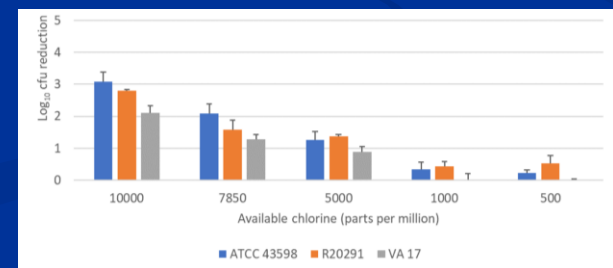
Cadnum JL. Comment on the effectiveness of sodium hypochlorite against *C difficile* spores. Microbiology 2024.



10
min

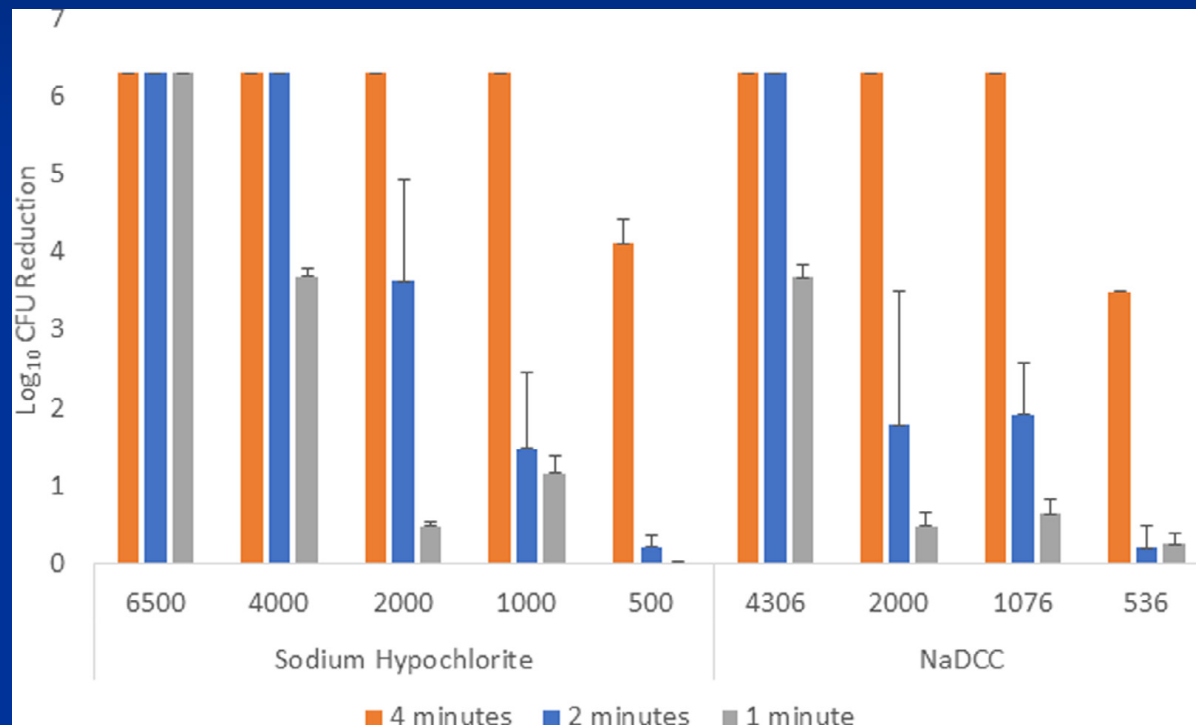


5
min



1
min

Know your disinfectants: Dilute chlorine-based disinfectants have reduced activity versus *Candida auris*



NaDCC = sodium dichloroisocyanurate

Kumar J.A Are reduced concentrations of chlorine-based disinfectants effective against *Candida auris*? Am J Infect Control 2020;48:448-450 (>4,000 ppm chlorine effective against *C. auris* with 1 minute contact time; lower concentrations only effective with 4-minute contact time).

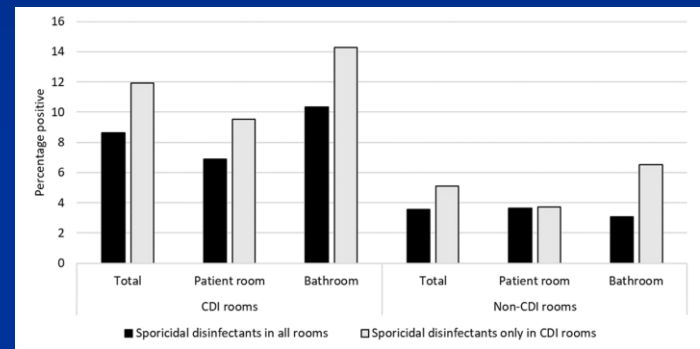
Conclusions

- Emergence of reduced susceptibility to disinfectants is not a major clinical problem, but inappropriate use may potentially lead to quat resistance
- Know your disinfectants: concentration, contact time

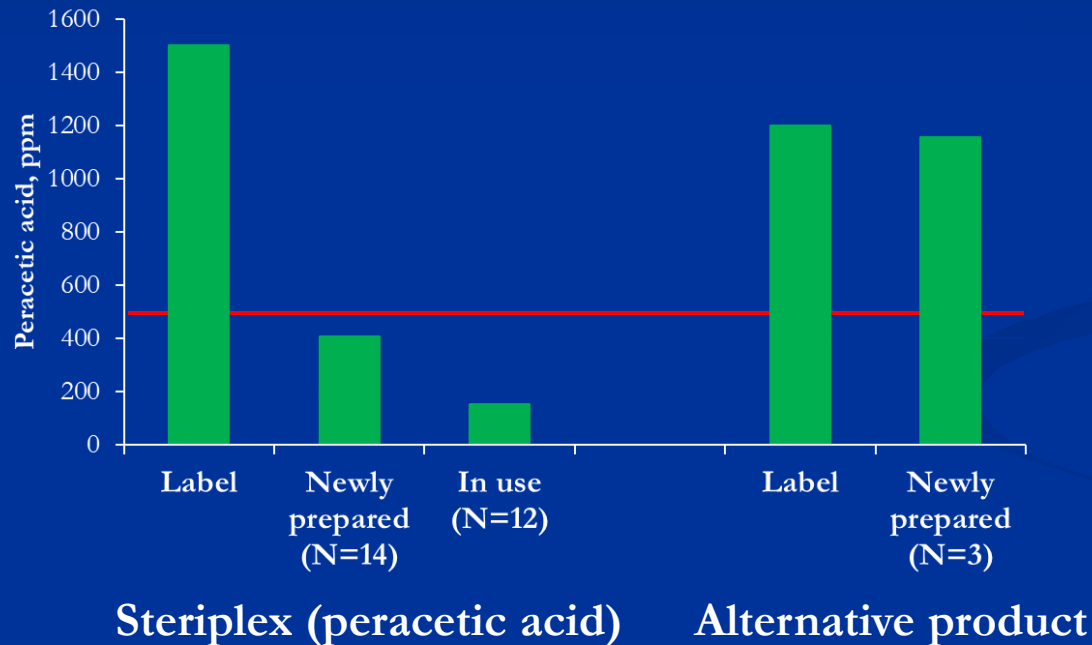
Question 2. What is the most likely reason for positive cultures after cleaning?

- A. Surfaces not wiped
- B. Disinfectant used incorrectly (e.g., inadequate contact time)
- C. Incorrect product used
- D. Disinfectant not working appropriately

Contamination AFTER cleaning



Disinfectant not working: A defective peracetic acid disinfectant



Malfunction of the Smart cap reservoir led to insufficient activator component

Cadnum JL. An increase in healthcare-associated CDI associated with use of a defective peracetic acid-based disinfectant. ICHE 2017.

Automated disinfectant dispensers

- Disinfectants are often dispensed from automated systems that mix water with concentrated disinfectant
- Manufacturers provide guidance for monitoring because there is the potential for malfunction or human error



Quaternary ammonium
disinfectant diluted 1:256

Automated disinfectant dispensing systems



Chemical
Management
System



Dilution and
Dispensing System



Peracetic acid
dispenser

Previous studies raising concerns about automated dispensers

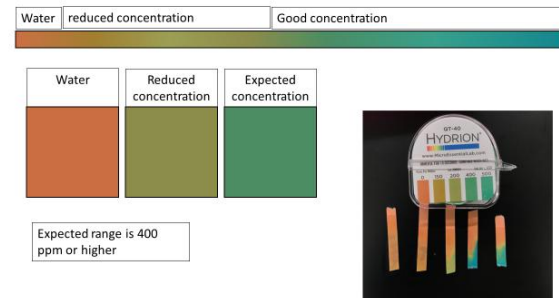
- Automated dispensers frequently delivered hydrogen peroxide levels too high or low (2009)¹
- Peracetic acid (OxyCide) concentrations often too high or too low (NIOSH 2017)²
- Variable quaternary ammonium concentrations-resolved after manufacturer installed water pressure regulators (2016)³

1. O'Neill C. Quality control is indispensable for automated dilution systems with accelerated hydrogen peroxide. Can J Infect Control 2009;24:226-8; 2. Hawley B. Evaluation of exposure to a new cleaning and disinfection product and symptoms in hospital employees. NIOSH health hazard evaluation report, HHE 2015-0053-3269, 2017. Available at: <https://stacks.cdc.gov/view/cdc/44556>; 3. Boyce JM. Quaternary ammonium disinfectant issues encountered in an environmental services department. ICHE 2016;37:340-2.

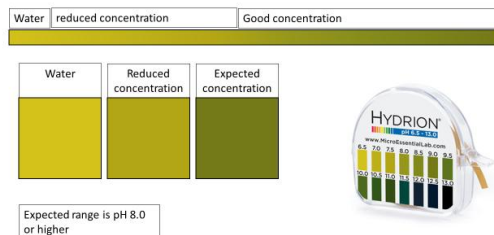
Multicenter evaluation of dispensers

- 10 hospitals from 4 healthcare systems in 5 states
- Collect disinfectant dispensed from the automated dispensers and in use containers
- Test level of disinfectant and pH
- Assess current methods for monitoring

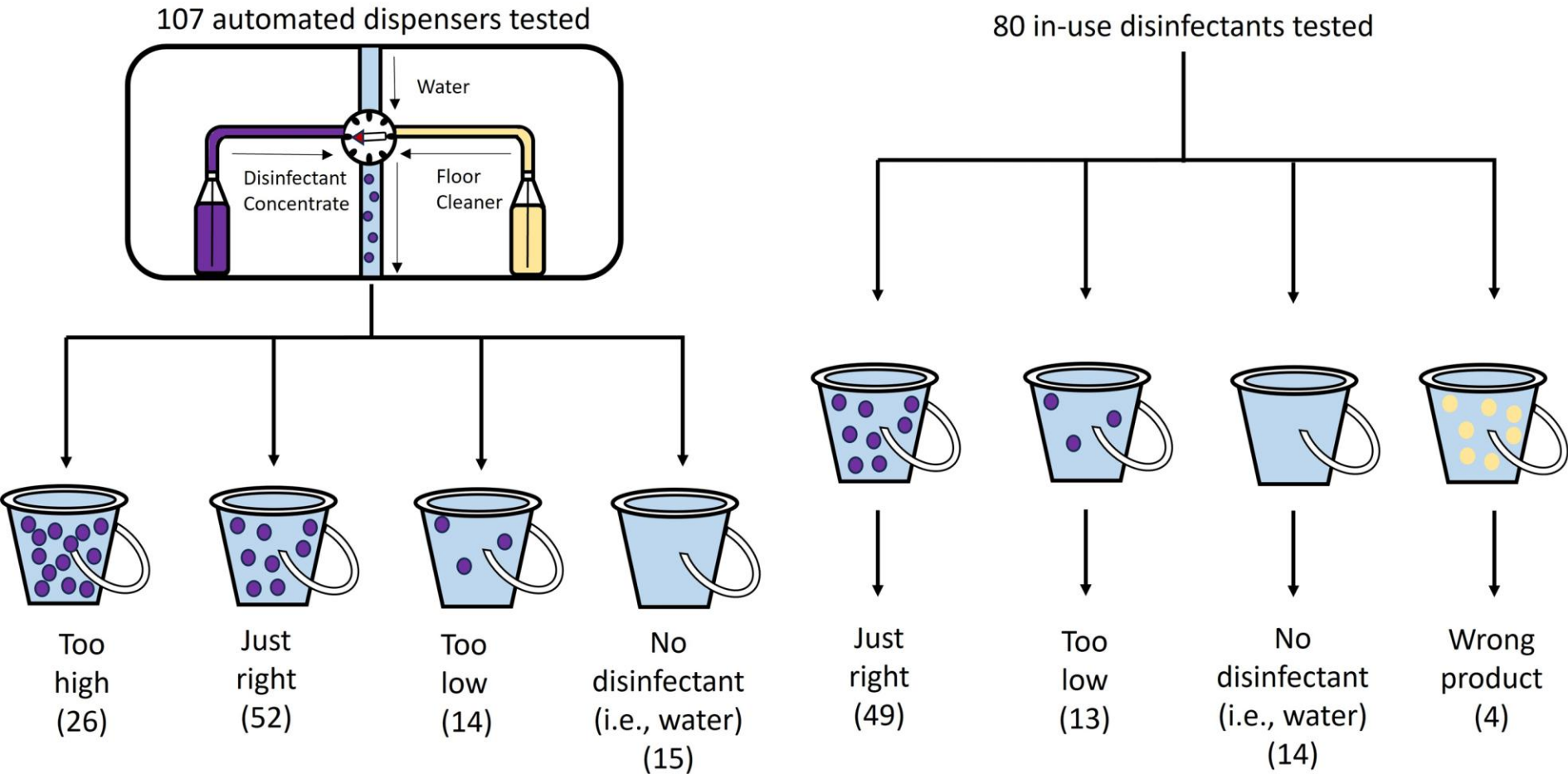
Quat test paper (Hydriion QT-40)



pH test paper (Hydriion 6.5-13.0)



Malfunction of automated disinfectant dispensers was common in 9 of 10 hospitals

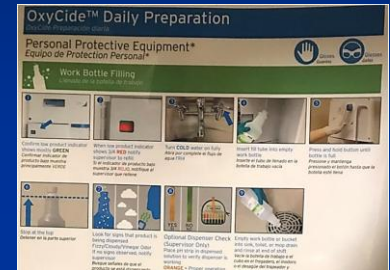


Conclusion: There is a need for improved monitoring of automated disinfectant dispensers

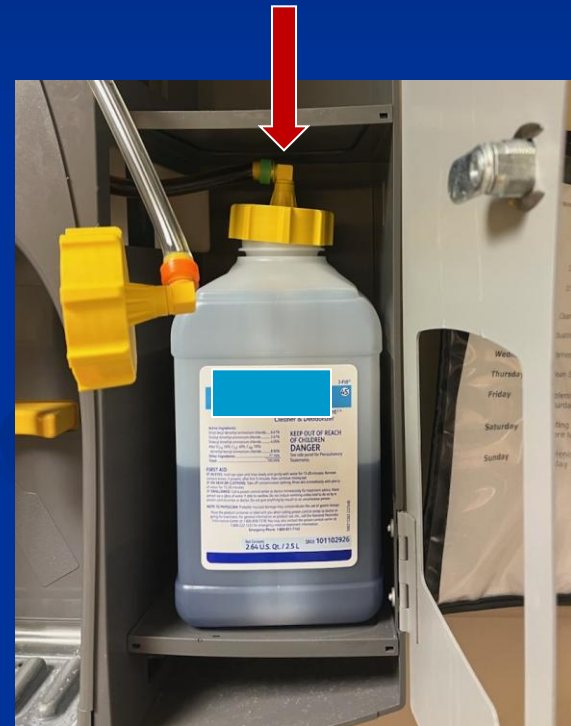
Cadum JL. Dilution dysfunction: evaluation of automated disinfectant dispenser systems in 10 hospitals demonstrates a need for improved monitoring to ensure that correct concentrations are delivered. ICHE 2024.

Are the manufacturers aware of the potential for dispenser malfunction?

- Large poster by each dispenser
- “Look for signs that product is being dispensed (fizzy/cloudy/vinegar odor). If no signs notify supervisor.”
- “Optional pH check (supervisor) to verify dispenser is working. Orange = proper operation; Green = call for service.”



Reasons for malfunction: container top not connected correctly

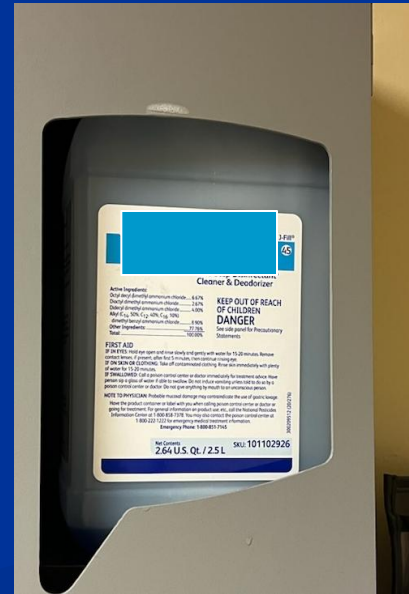


Reasons for malfunction: amount of concentrate running low in container

Low concentrate level



Difficult to visualize level when door closed

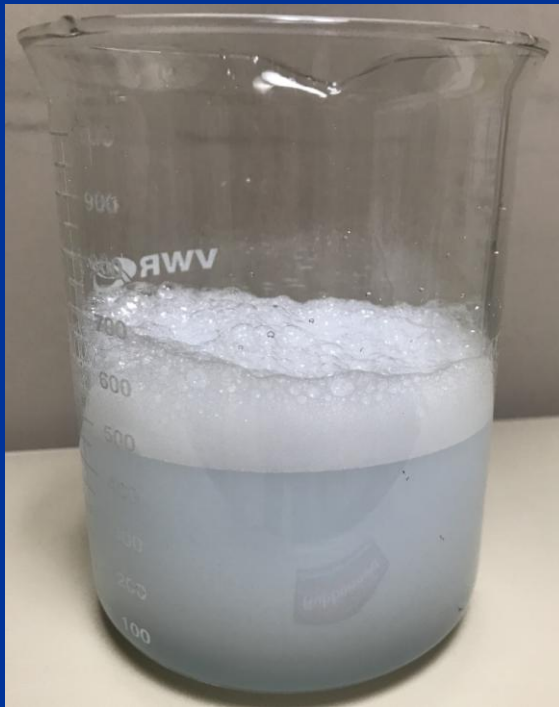


Low product indicator malfunction

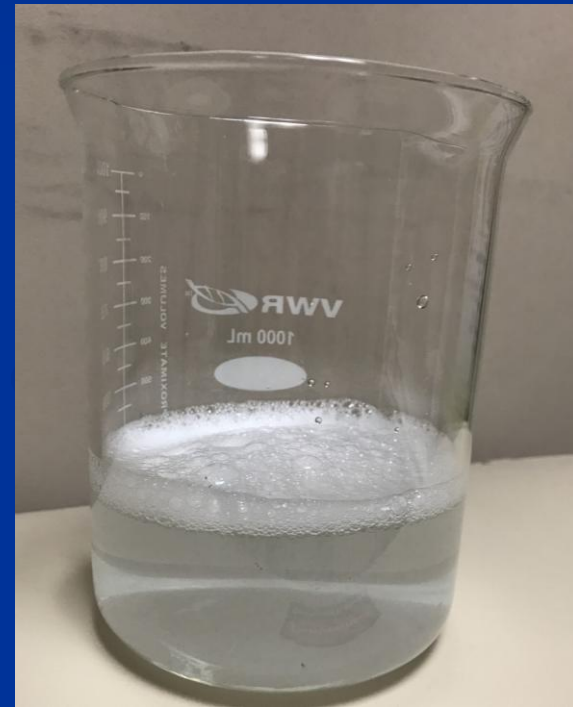


Difficulty telling that the concentration is low

Virex Plus

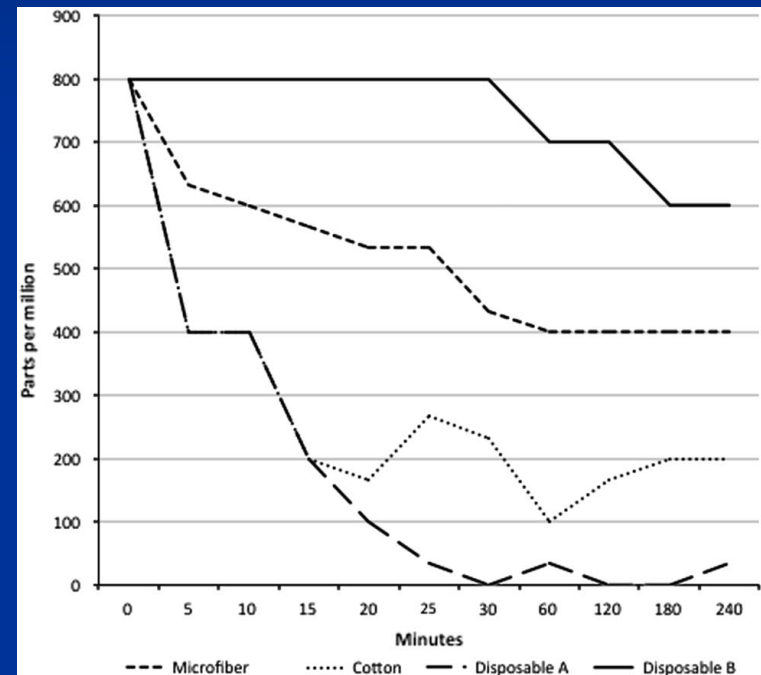


Water



Binding to wipes can reduce quaternary ammonium concentrations

- Wipes reduced quaternary ammonium concentrations to a variable degree when submerged for long periods
- Recommended “dip and wipe” method – submerge for only 5-10 seconds before use



Boyce JM. Quaternary ammonium disinfectant issues encountered in an environmental services department. ICHE 2016;37:340-2.

Conclusion: You can't improve what you don't measure

- There is a need for improved monitoring of automated disinfectant dispensers

Fluorescent marker (laundry detergent)



Colorimetric assay for chlorhexidine



Carling PC. Improved cleaning of patient rooms using a new targeting method. *Clin Infect Dis* 2006;42:385-8; Supple L, Kumaraswami M, et al. Chlorhexidine Only Works If Applied Correctly: Use of a Simple Colorimetric Assay to Provide Monitoring and Feedback on Effectiveness of Chlorhexidine Application. *ICHE* 2015;36:1095-7; Cadnum JL. Use of a simple colorimetric assay to provide monitoring and feedback on adherence to chlorhexidine bathing protocols. *AJIC* 2020;48:469-70.

Can we identify new approaches to identify malfunctioning dispensers?

- Hydrophobic wipes
(Contec)
- Identifies quat dispensers
that dispense water
because water is not
absorbed into the wipe

Question 3. There is an outbreak of multidrug-resistant *Pseudomonas aeruginosa* in the ICU.
Which interventions would you consider?

- A. Environmental cleaning & disinfection intervention
- B. Reinforce chlorhexidine bathing
- C. Regular disinfection of all sink drains

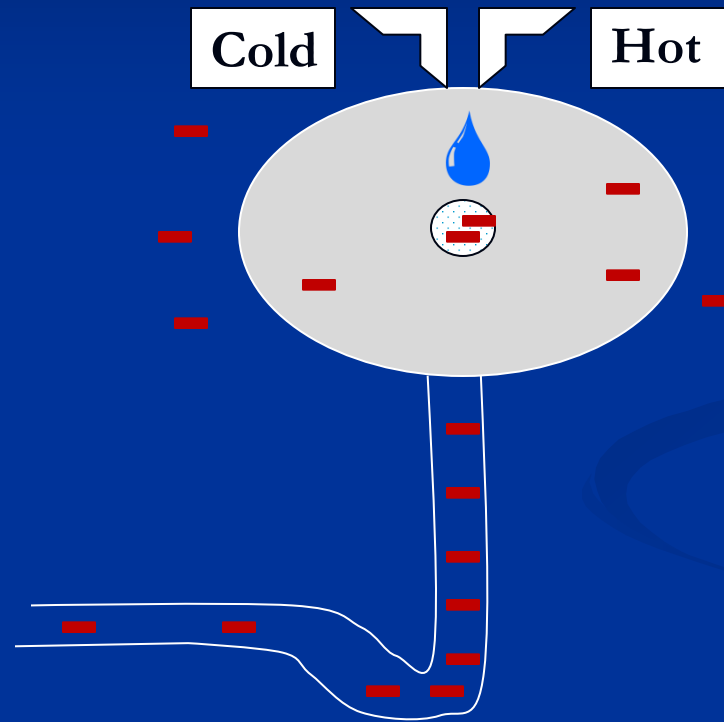
Patel A. Effectiveness of daily chlorhexidine bathing for reducing gram-negative infections: A meta-analysis. ICHE 2019;40:392-99 (no reduction in infections due to GNB).

Evidence that cleaning interventions may reduce gram-negative infections

- Multicenter, cluster-randomized, crossover trial¹
 - ATP monitoring reduced MDRO infections & resistant gram-negative infection/colonization
- UV light²
 - 40 VA hospitals reported UV-C use: associated with reduced hospital onset gram-negative bloodstream infections (IRR 0.813)

1. Ziegler MJ. Stopping Hospital Infections With Environmental Services (SHINE): A Cluster-randomized Trial of Intensive Monitoring Methods for Terminal Room Cleaning on Rates of MDROs in the ICU. Clin Infect Dis 2022; 2. Goto M. Effectiveness of UVC Disinfection on Hospital-Onset Gram-Negative Rod BSI: A Nationwide Stepped-Wedge Time-Series Analysis. Clin Infect Dis 2023.

From sink to patient



Swab below
strainer

Hota S. Outbreak of multidrug-resistant *P. aeruginosa* colonization and infection secondary to imperfect intensive care unit room design. ICHE 2009;30:25-33; Kotay S. Spread from the sink to the patient: in situ study using GFP expressing *E. coli* to model bacterial dispersion from sink trap reservoirs. Appl Env Microbiol 2017; Hajar Z. Dispersal of gram-negative bacilli from contaminated sink drains to cover gowns and hands during hand washing. ICHE 2019;40:460-2.

Hand hygiene guidelines: take steps to reduce transmission from sinks and drains

■ Essential practices

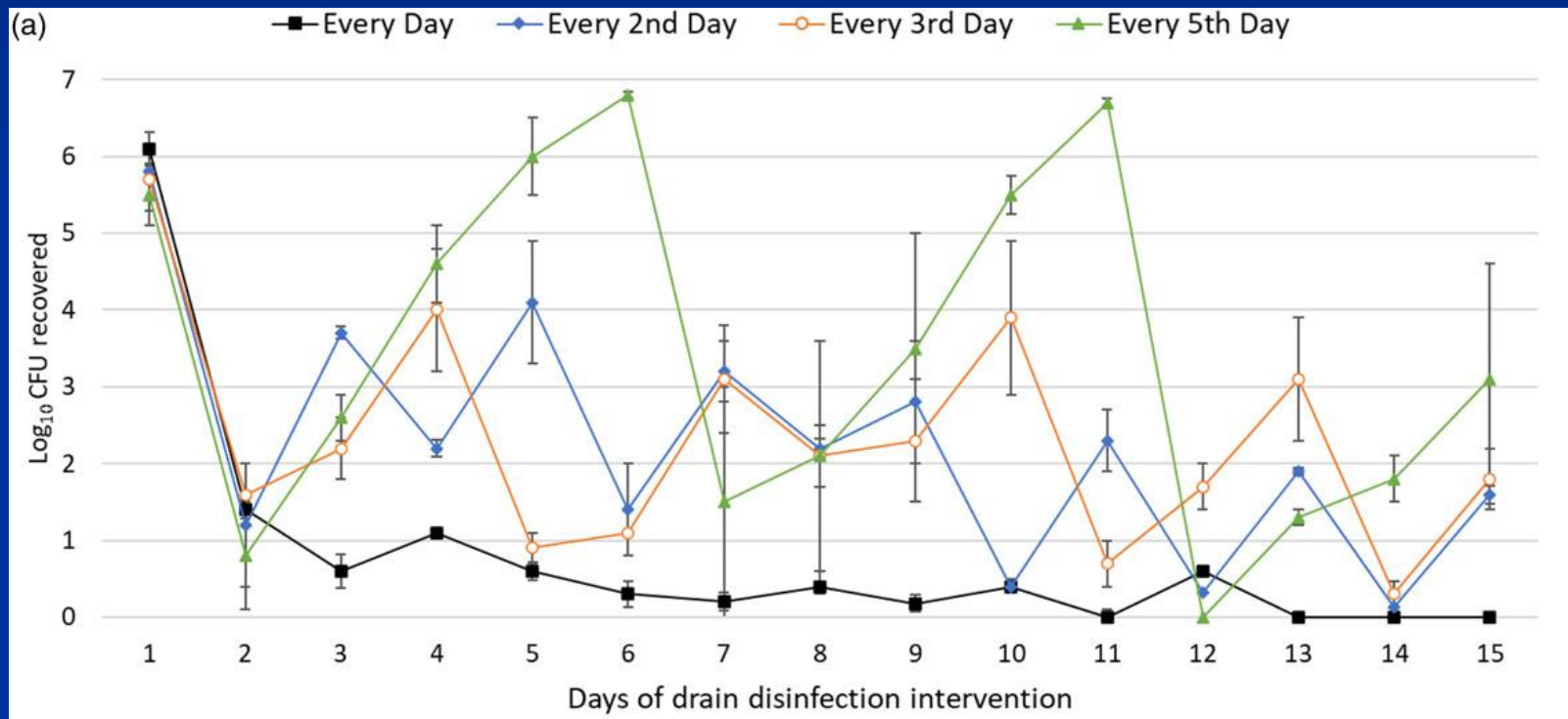
- Dedicated hand washing sinks
- Avoid pouring substances that promote biofilm
- Clean bowls and faucets daily
- No patient care items within 3 feet

■ Additional approach: Outbreaks - disinfect sink drains using product with biofilm claims

Concerns about sink disinfection: Uncertainty regarding sink contribution to transmission

- Systematic review of 52 studies implicating sinks
- Evidence is circumstantial
- Directionality challenging to establish
- Attributable fraction related to sinks unknown

Concerns about sink disinfection: daily or every other day application required

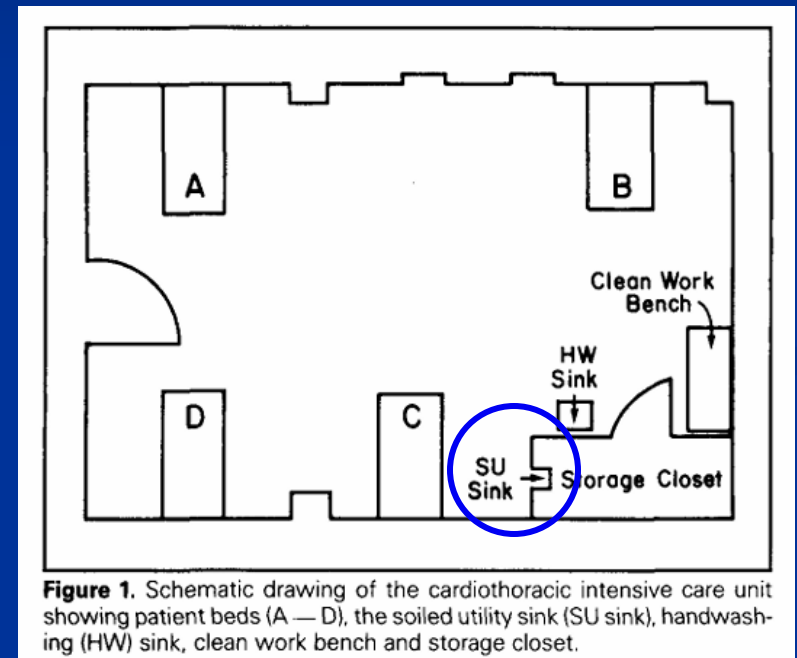


Disinfectant = hydrogen peroxide and peracetic acid

Varghese MM. What is the optimal frequency of sink drain decontamination with a foam disinfectant? Infect Control Hosp Epidemiol 2024.

Concerns about sink disinfection: sinks may vary in risk for dispersal

- 1 ICU sink linked to an outbreak
- Soiled utility sink dispersed GNB to environment and personnel
- Outbreak controlled by measures including discontinued use of the soiled utility sink



Dandalides PC. Postoperative infections following cardiac surgery: association with an environmental reservoir in a cardiothoracic intensive care unit. *Infect Control* 1984;5:378-84.

Identifying and remediating super-splasher sinks

- Dispersal of fluorescent marker from below strainer predicted dispersal of GNB
- Plumbing intervention: reducing the flow rate and/or eliminating obstruction prevented dispersal

Dispersal of water droplets



Backup of water

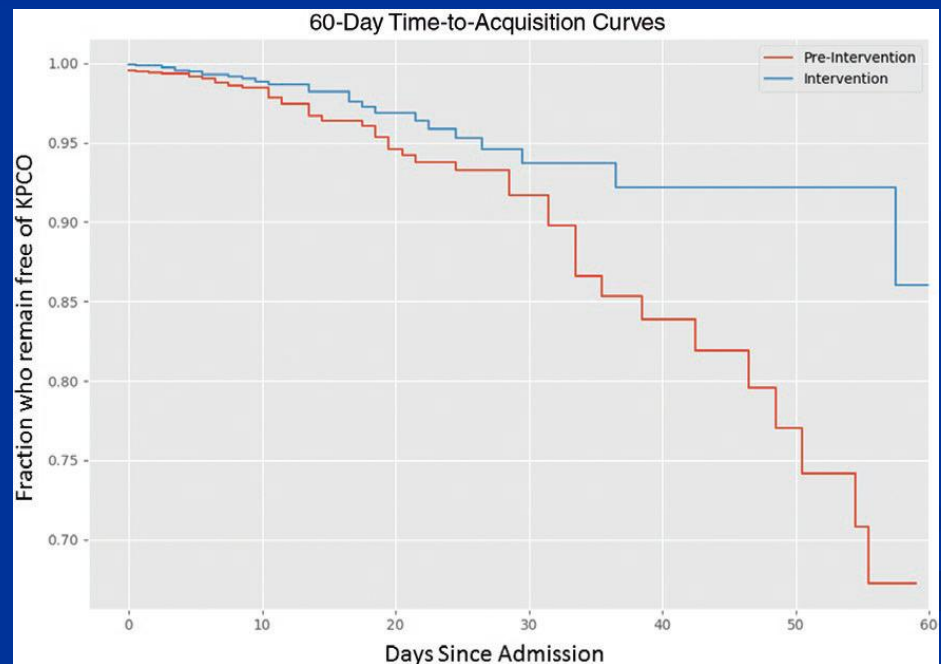


A wastewater intervention reduced transmission of *K. pneumoniae*

60 hopper covers and 23 sink trap devices installed



Acquisition of carbapenemase-producing *K. pneumoniae*



Mathers AJ. ICU Wastewater Interventions to Prevent Transmission of Multispecies *Klebsiella pneumoniae* Carbapenemase-Producing Organisms. Clin Infect Dis 2018

Conclusions

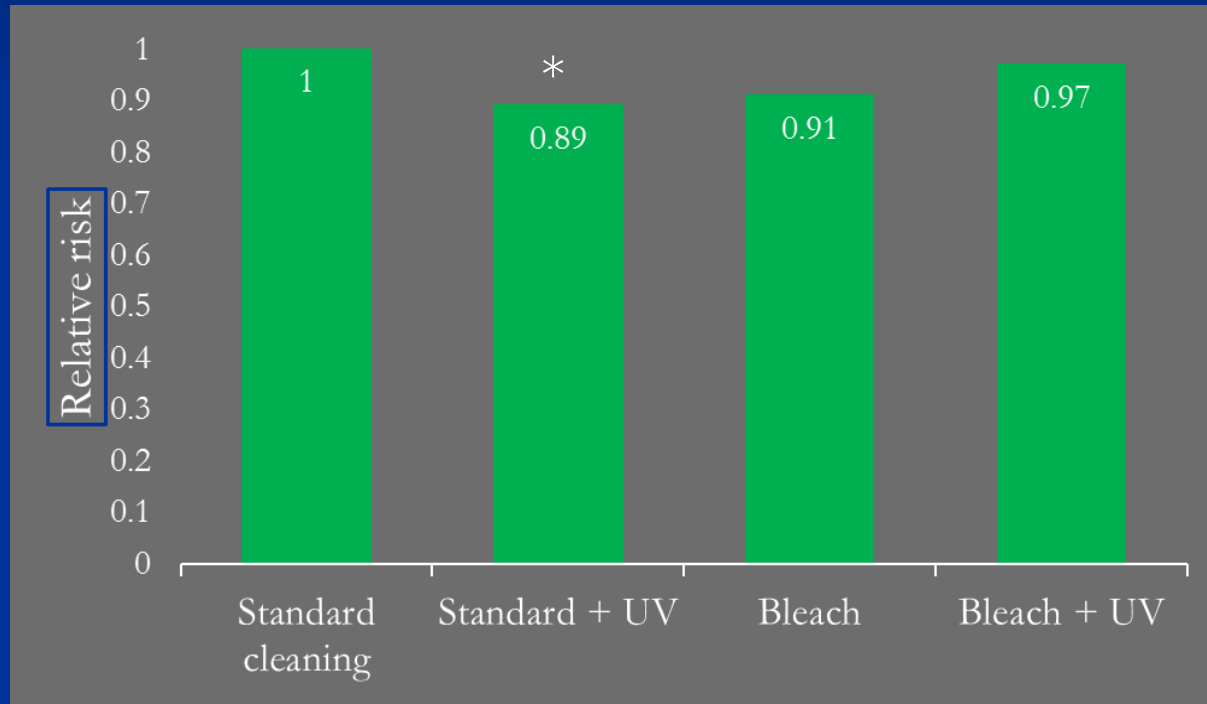
- Reducing the burden of sink drain colonization is challenging
- Interventions that focus on reducing dispersal from colonized sink drains may be more effective

Question 4. Should your facility use UV-C room decontamination devices?

Yes	No
Multiple before-after studies suggest a decrease in infections	Low-quality evidence
CDC randomized trial: Addition of UV to standard cleaning reduced healthcare-associated pathogens and hospital-wide CDI and VRE	Findings not consistent: No decrease in MDROs or hospital-wide CDI and VRE when UV added to bleach (only when added to Quat)
Recommended by some experts	CDI guidelines: limited data to recommend devices for CDI prevention (no recommendation)

Donskey CJ. Decontamination devices in health care facilities: Practical issues and emerging applications. Am J Infect Control 2019;47S:A23-A28.

Impact of enhanced post-discharge room disinfection on CDI rates



Anderson DJ. Effectiveness of targeted enhanced terminal room disinfection on hospital-wide acquisition and infection with multidrug-resistant organisms and *C difficile*: a secondary analysis of a multicentre cluster randomised controlled trial with crossover design (BETR Disinfection). Lancet Infect Dis 2018.

Cluster randomized crossover trials of UV-C room decontamination

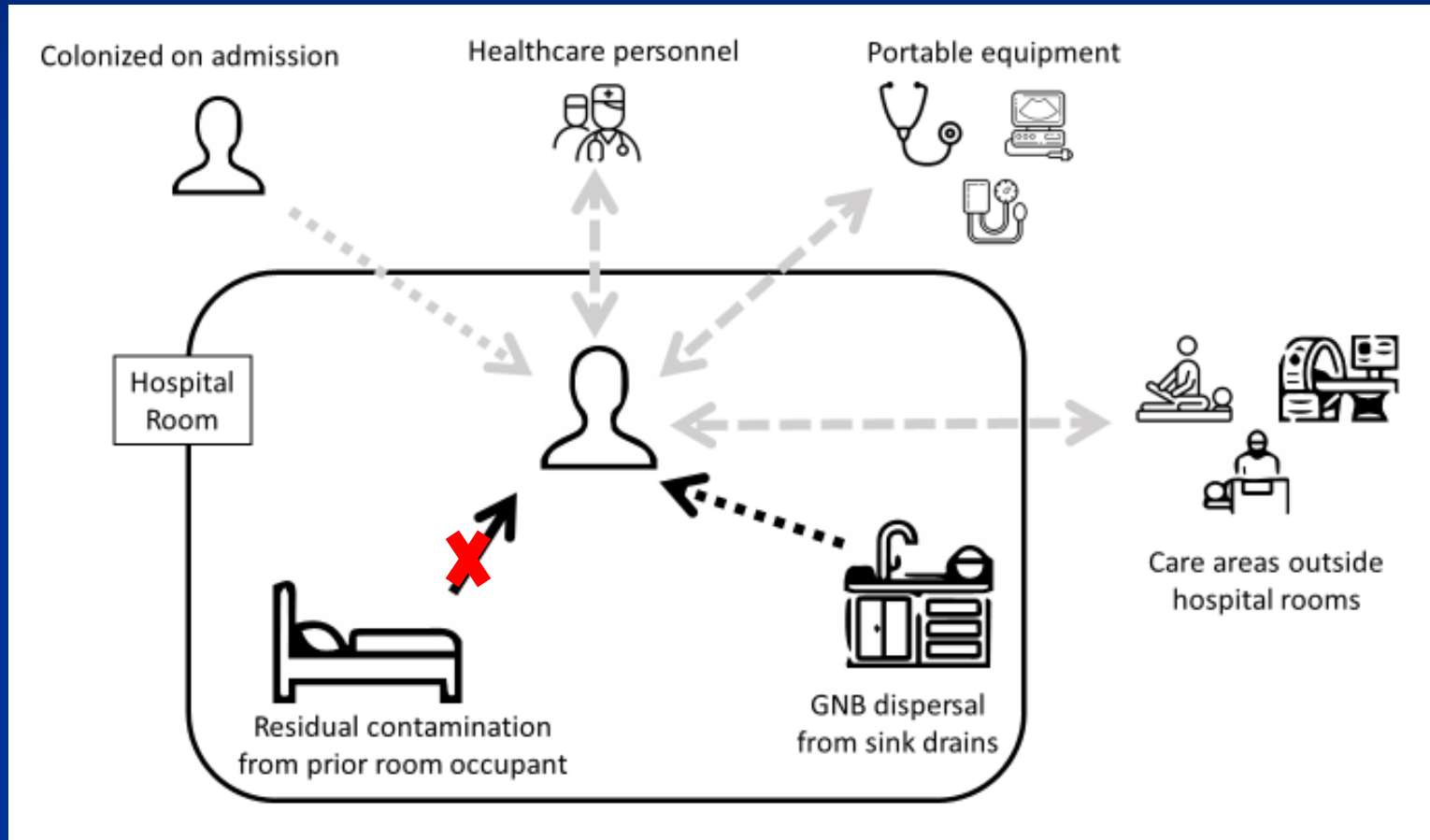
Setting	Findings
Nine hospitals ^{1,2}	Decrease in MDROs and hospital-wide CDI (11%) and VRE (44%) when UV added to quat but not when added to bleach
4 cancer wards & 1 organ transplant unit ³	No reduction in new VRE infections or <i>C. difficile</i> infections
15 wards in 2 hospitals (pulsed xenon devices) ⁴	No reduction in clinical cultures positive for environmentally implicated HAIs (VRE, MRSA, resistant GNB) and CDI

1. Anderson DJ. Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *C. difficile* (the Benefits of Enhanced Terminal Room Disinfection study): a cluster-randomised, multicentre, crossover study. *Lancet* 2017; 2. Anderson DJ. Effectiveness of targeted enhanced terminal room disinfection on hospital-wide acquisition and infection with multidrug-resistant organisms and *C. difficile*: a secondary analysis of a multicentre cluster randomised controlled trial with crossover design (BETR Disinfection). *Lancet Infect Dis* 2018; 3. Rock C. Ultraviolet-C Light Evaluation as Adjunct Disinfection to Remove Multi-Drug Resistant Organisms. *Clin Infect Dis* 2021; 4. Dhar S. Lowering the Acquisition of Multidrug-Resistant Organisms (MDROs) With Pulsed-xenon (LAMP) Study: A Cluster-Randomized, Controlled, Double-Blinded, Interventional Crossover Trial. *Clin Infect Dis* 2024.

Conclusion

- UV-C room devices are effective in reducing contamination, but there is limited high-quality evidence suggesting that use of UV-C will reduce HAIs

Post-discharge UV-C only addresses one source of transmission



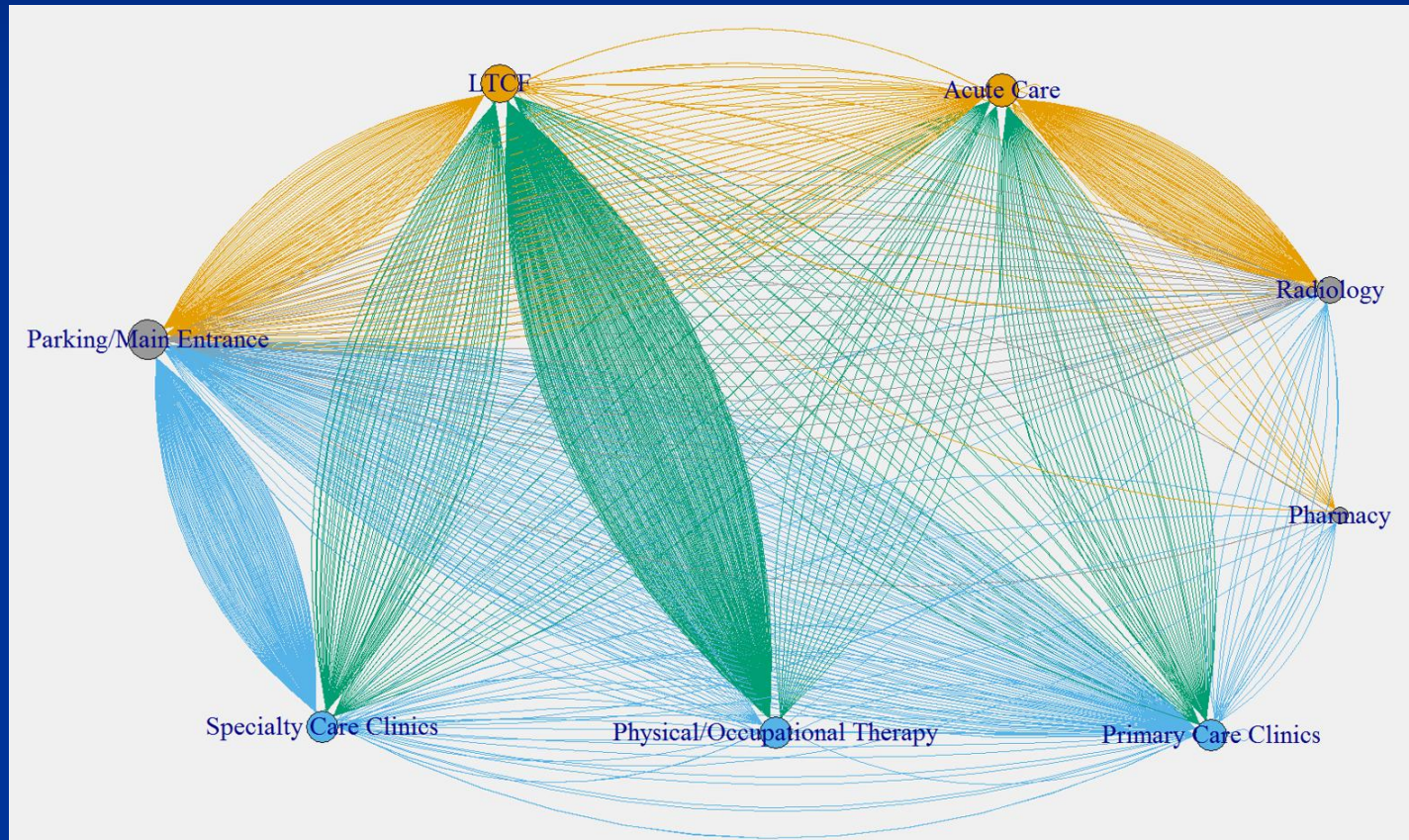
Goto M, Donskey CJ. More High-Quality Evidence Curbing Our Enthusiasm for Enhanced Terminal Decontamination of Hospital Rooms with No-Touch Technologies: Is It Lights Out for UV-C?. Clin Infect Dis 2024.

Question 5. Will improved decontamination of portable equipment reduce HAIs?

- Portable equipment
 - Often contaminated
 - Rarely cleaned
 - Frequently in contact with patients
 - Implicated as a source of transmission

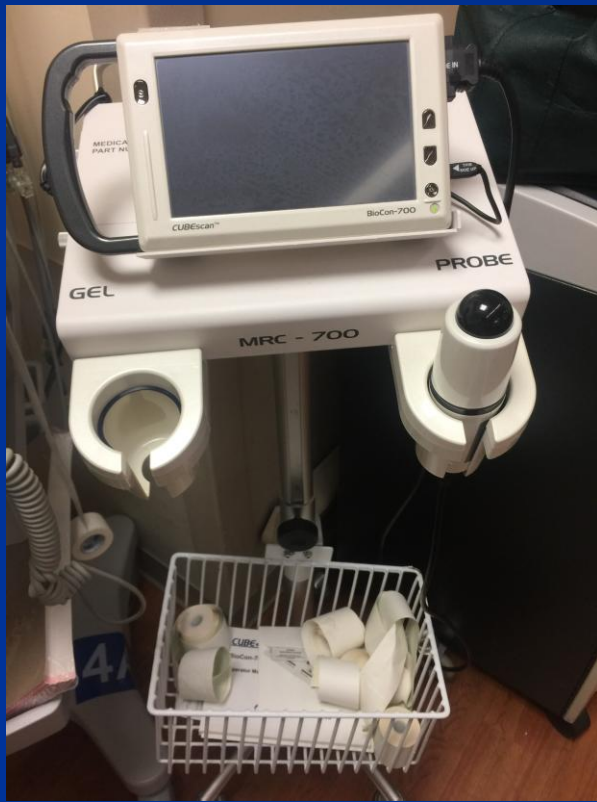
Donskey CJ. Beyond high-touch surfaces: Portable equipment and floors as potential sources of transmission of health care-associated pathogens. *AJIC* 2019; Kanamori H. The role of patient care items as a fomite in healthcare-associated outbreaks and infection prevention. *Clin Infect Dis* 2017; Eyre DW. A *C. auris* outbreak and its control in an intensive care setting. *NEJM* 2018;379:1322-31.

Spores on wheels: Movement of wheelchairs within a hospital and LTCF



Jencson AL. Spores on wheels: Wheelchairs are a potential vector for dissemination of pathogens in healthcare facilities. Am J Infect Control 2019.

Portable equipment as a vector for ward to ward transmission



Alhmidi H. Sharing is not always a good thing: Use of a DNA marker to investigate the potential for ward-to-ward dissemination of healthcare-associated pathogens. ICHE 2021.

CLEEN randomized trial

- 10 non-ICU hospital wards – 5002 patients
- 3 hours additional cleaning of shared medical equipment each weekday
- Improved cleaning – fluorescent marker removal (18% to 57%)
- 5% absolute reduction in HAIs (15% to 10%)
 - 35% relative reduction

Browne K. Investigating the effect of enhanced cleaning and disinfection of shared medical equipment on HAIs in Australia (CLEEN) randomized trial. Lancet ID 2024.

Conclusion

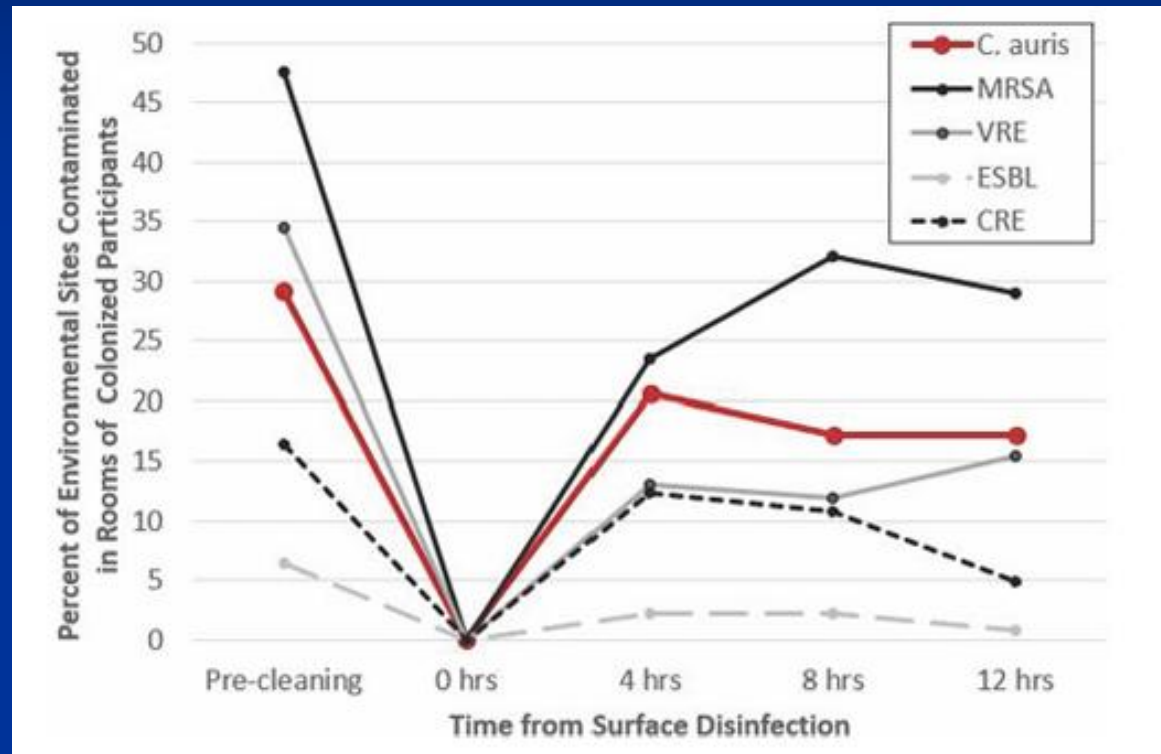
- There is a need for more studies to identify effective processes for decontamination of equipment and to assess their impact on HAIs

Question 6. Are emerging continuous decontamination technologies effective and safe?



Donskey CJ. Beyond high-touch surfaces: Portable equipment and floors as potential sources of transmission of health care-associated pathogens. AJIC 2019.

Rapid recontamination of surfaces after cleaning rooms of *Candida auris* patients



Sansom SE. Rapid Environmental Contamination with *C. auris* and Multidrug-Resistant Bacterial Pathogens Near Colonized Patients. Clin Infect Dis 2023;ciad752; Hardy KJ. Rapid recontamination with MRSA of the environment of an ICU after decontamination with hydrogen peroxide vapour. J Hosp Infect 2007;66:360-8.; Alhmidi H. Shedding of MRSA by colonized patients during procedures and care activities. Infect Control Hosp Epidemiol 2019;40:328-32.

The quest for the holy grail: continuous decontamination between episodes of manual cleaning

- Effective
- Surfaces and air
- Automated
- Safe
- Reasonably priced



Candidate technologies

- Continuously active surface disinfectants
- Antimicrobial gases
- Ultraviolet light



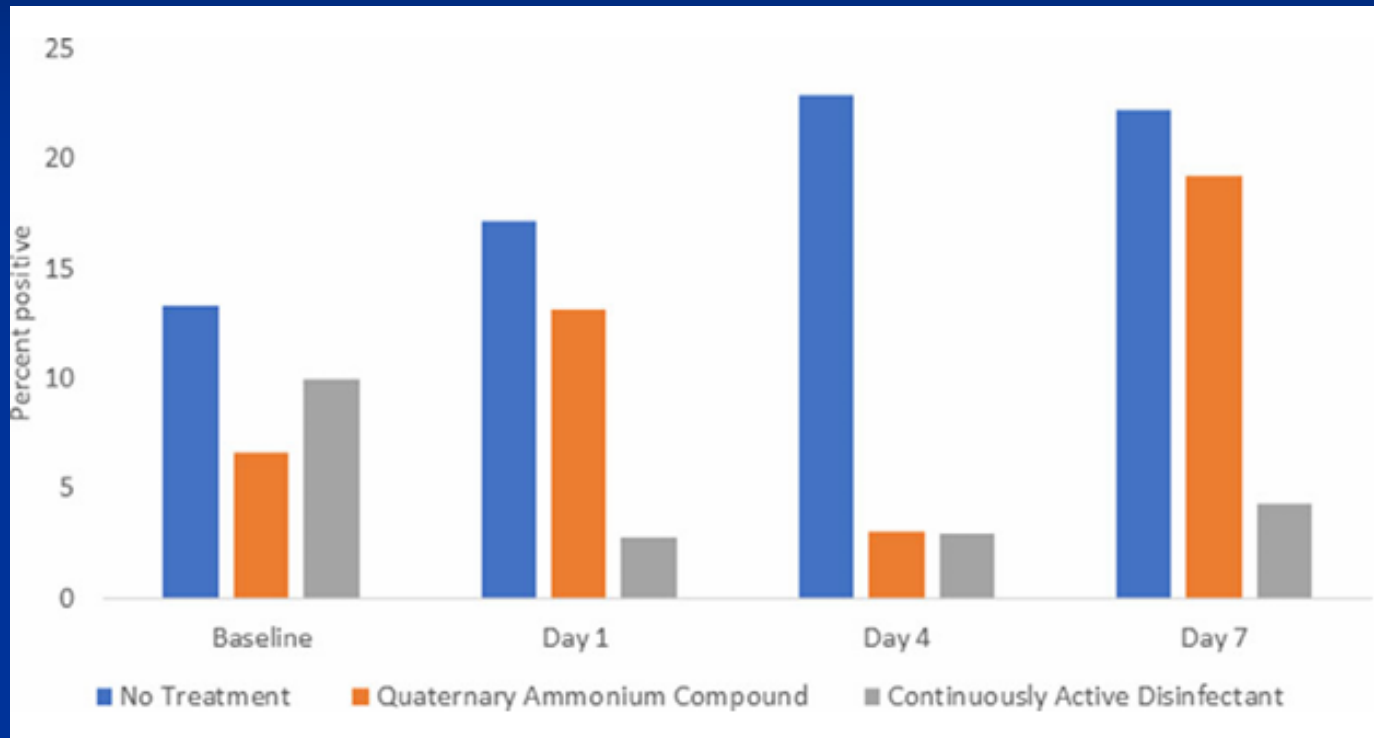
Continuously active quaternary ammonium disinfectants

- Contain polymer coatings that bind to surfaces resulting in persistent antimicrobial activity
- Sustained antimicrobial activity against several pathogens after 24 hours following multiple wet and dry abrasion cycles
- Active against SARS-CoV-2

Redmond SN. Evaluation of a continuously active disinfectant for decontamination of portable medical equipment. Infect Control Hosp Epidemiol 2021 May 26;1-3;

Rutala WA. Continuously Active Disinfectant Inactivates SARS-CoV-2 and Human Coronavirus 229E Two Days After the Disinfectant Was Applied and Following Wear Exposures. Infect Control Hosp Epidemiol 2021 Dec 2:1-9.

Continuously active disinfectant for decontamination of equipment



Redmond SN. Evaluation of a continuously active disinfectant for decontamination of portable medical equipment. ICHE 2021.

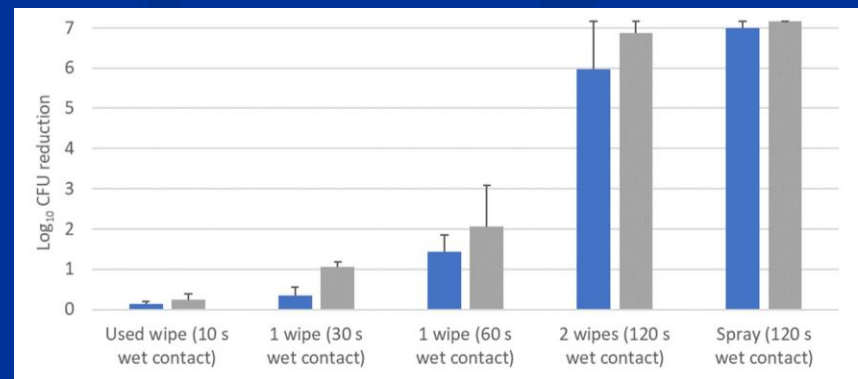
Continuously active quaternary ammonium disinfectants

- Easily removed
- Lab test methods exaggerate efficacy
- Method of application impacts real-world efficacy
- Clinical studies: mixed results

Easily removed



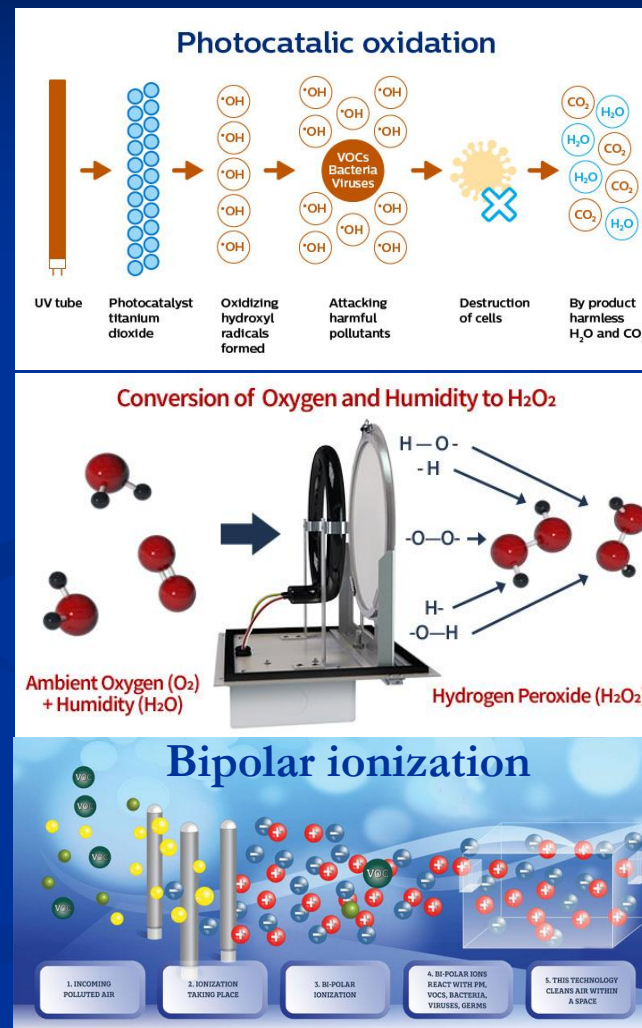
Different application methods



Cadnum JL. Why is there a discrepancy between laboratory test results and real-world efficacy of continuously active quaternary ammonium disinfectants? Infect Control Hosp Epidemiol 2024.

Electronic air cleaning technologies

- Photocatalytic oxidation
 - UV + titanium dioxide catalyst produces electrons that convert water to reactive oxygen species, hydroxyl radicals
- Dilute/dry hydrogen peroxide
 - Light + catalyst
- Bipolar ionization
 - High voltage electrodes create positive and negative ions in air from water and oxygen



https://nyssfa.com/images/ASHRAE-Filtration_Disinfection-C19-Guidance.pdf;

Residential Air Cleaners A Technical Summary EPA 402-F-09-002, 2018

Antimicrobial gases (electronic air cleaning technologies)

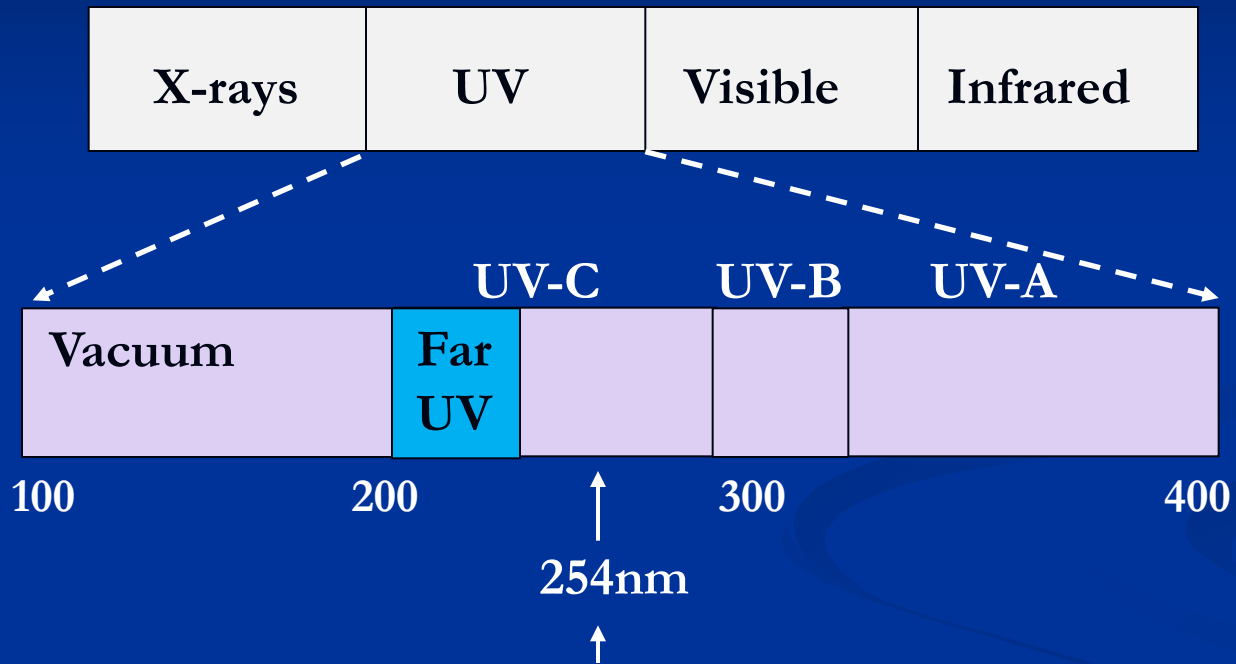
- Limited efficacy data
 - Some quasi-experimental studies show reductions in surface contamination with dry hydrogen peroxide¹
 - Lab testing: no reduction in bacterial pathogens²
- Safety concerns (CDC/ASHRAE)
 - Considered “emerging” – exercise caution
 - May produce ozone or other harmful byproducts

1. Donskey CJ. Continuous surface and air decontamination technologies: Current concepts and controversies. AJIC 2023;

2. Rutala WA. Evaluation of dilute hydrogen peroxide technology for continuous room decontamination of multidrug-resistant organisms. ICHE 2019; 3. American Society of Heating, Refrigerating and Air-Conditioning Engineers.

https://nyssfa.com/images/ASHRAE-Filtration_Disinfection-C19-Guidance.pdf; Residential Air Cleaners A Technical Summary EPA 402-F-09-002, 2018; 4. <https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html>

Ultraviolet light



Far UV-C light (222 nm)

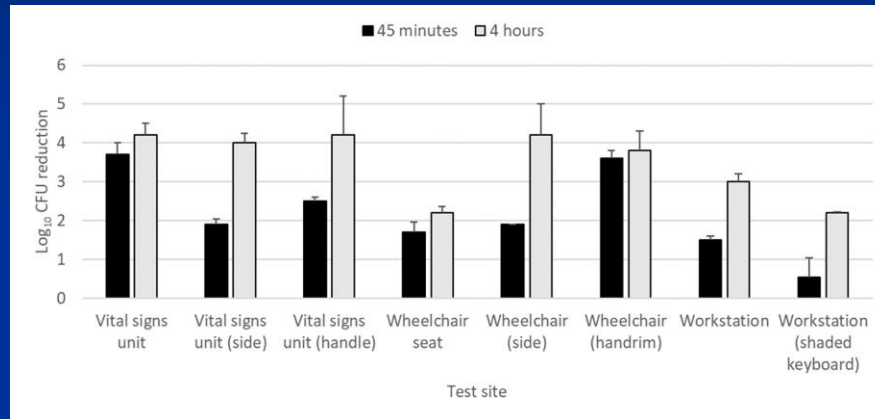
Far-UV is a promising technology that may well prove to be effective at treating air and surfaces, without some of the safety precautions required for standard UVGI. In the near term, whole-room UVGI is best viewed as new and emerging technology.

<https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html>

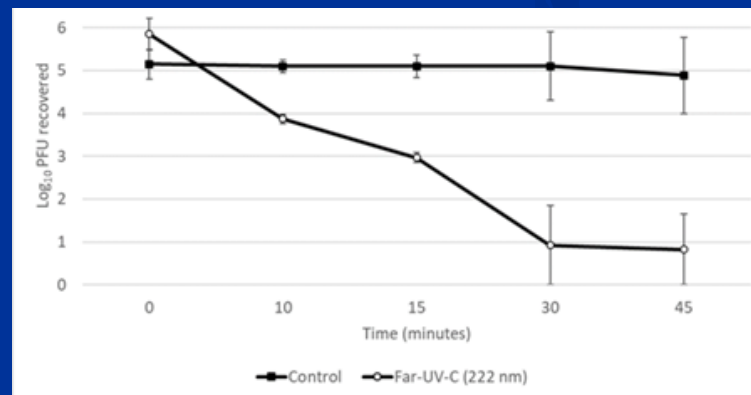


Far UV-C light is effective

Reduction on portable equipment



Reduction in aerosolized virus



Memic S. Efficacy of a far-ultraviolet-C light technology for continuous decontamination of air and surfaces. *Infect Control Hosp Epidemiol* 2024;45:132-4.

Opportunity: Intermittent delivery of far UV in clinical areas when people are not present

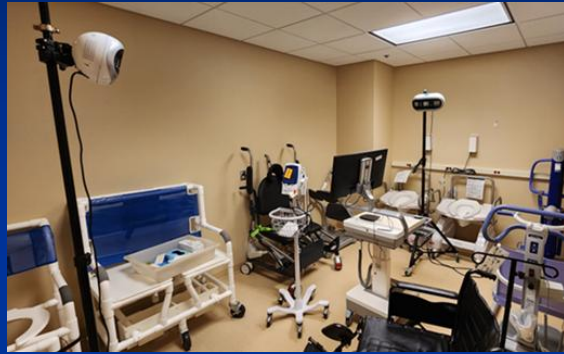
- Wall- or ceiling mounted
- Detect people in area of exposure
- Can be programmed to only deliver far UV when people are not present
- Minimal risk if accidental exposure occurred



Memic S. A novel approach for safe and automated implementation of far UV-C light decontamination in clinical areas. ASHE 2024.

Potential applications

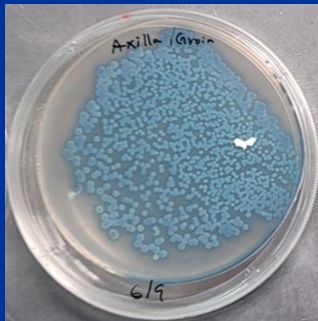
Equipment rooms



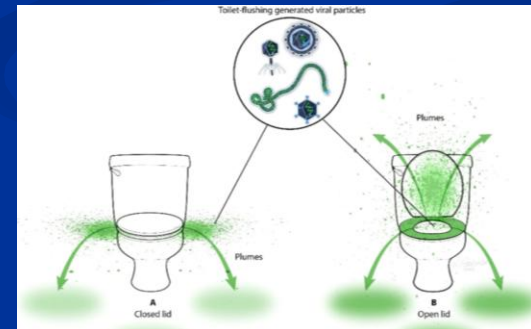
Sinks



Emerging pathogens (*C. auris*)



Bathrooms



Kaple CE. A far UV-C light technology is effective for decontamination of items in proximity to sinks and is enhanced by a far UV-C reflective surface. ICHE 2024; Kaple CE. Efficacy of a far UV-C light technology for decontamination of bathrooms. ARIC 2024; Memic S. Evaluation of an automated wall-mounted far UV-C light technology for continuous or intermittent decontamination of *Candida auris* on surfaces. Pathogens and Immunity 2024; Memic S. Evaluation of a far ultraviolet-C device for decontamination of portable equipment in clinical areas. Submitted.

Opportunity: Work with early adopters of far UV to obtain information on safety

- Ohio dental office
- Lamps installed in 5 procedure rooms in 2020
- Used for thousands of hours with no reported adverse effects

We are “pleased to announce the most advanced high-level disinfection system available anywhere in the world”



* A high photon energy lamp that is safe for people. It falls below the FDA threshold limit value (THV) for human exposure, it's used to disinfect air and surfaces from



Osborne AO. Evaluation of a wall-mounted far ultraviolet-C light device used for continuous air and surface decontamination in a dental office during routine patient care. ICHE 2024.

Summary

- Emergence of reduced susceptibility to disinfectants is not a major clinical problem, but inappropriate use may lead to quat resistance
- There is a need for improved monitoring of automated disinfectant dispensers
- Reducing the burden of sink drain colonization is challenging - interventions that focus on reducing dispersal may be more effective

Summary

- UV-C room devices reduce contamination, but there is limited high-quality evidence suggesting that use of UV-C will reduce HAIs
- More studies are needed to identify effective processes for decontamination of equipment and to assess their impact on HAIs
- There are promising continuous air and surface decontamination technologies