CHLORINE USE IN HEALTH CARE

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Centers for Disease Control and Prevention (CDC), Atlanta

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DISCLOSURES

- **Consultation**
  - Clorox
- **Honoraria**
  - 3M, Clorox
- **Grants to UNC or UNC Hospitals**
  - CDC, CMS, Nanosonics

LECTURE OBJECTIVES

- Review the role of the environment in transmission of nosocomial pathogens
- Review the properties of an ideal disinfectant
- Discuss bleach use in healthcare
  - Chemistry
  - Antimicrobial Efficacy
  - Safety
  - Healthcare Applications

DISINFECTION AND STERILIZATION

- EH Spaulding believed that how an object will be disinfected depended on the object's intended use.
  - CRITICAL - objects which enter normally sterile tissue or the vascular system or through which blood flows should be **sterile.**
  - SEMICRITICAL - objects that touch mucous membranes or skin that is not intact require a disinfection process (**high-level disinfection [HLD]**) that kills all microorganisms but high numbers of bacterial spores.
  - NONCRITICAL -objects that touch only intact skin require **low-level disinfection**.

Processing "Noncritical" Patient Care Objects

Classification:	Noncritical objects will not come in contact with mucous membranes or skin that is not intact.
Object:	Can be expected to be contaminated with some microorganisms.
Level germicidal action:	Kill vegetative bacteria, fungi and lipid viruses.
Examples:	Bedpans; crutches; bed rails; EKG leads; bedside tables; walls, floors and furniture.
Method:	Low-level disinfection

Low-Level Disinfection for "Noncritical" Objects

Exposure time ≥ 1 min

Germicide	Use Concentration
Ethyl or isopropyl alcohol	70-90%
Chlorine	100ppm (1:500 dilution)
Phenolic	UD
Iodophor	UD
Quaternary ammonium	UD
Improved hydrogen peroxide	0.5%, 1.4%

UD=Manufacturer's recommended use dilution

Environmental Contamination Leads to HAIs

- Evidence environment contributes
- Role-MRSA, VRE, *C. difficile*
- Surfaces are contaminated-~25%
- EIP survive days, weeks, months
- Contact with surfaces results in hand contamination
- Disinfection reduces contamination
- Disinfection (daily) reduces HAIs
- Rooms not adequately cleaned

Admission to Room Previously Occupied by Patient C/I with Epidemiologically Important Pathogen

- Results in the newly admitted patient having an increased risk of acquiring that pathogen by 39-353%
- For example, increased risk for *C. difficile* is 235% (11.0% vs 4.6%)

ALL "TOUCHABLE" (HAND CONTACT) SURFACES SHOULD BE WIPED WITH DISINFECTANT

"High touch" objects only recently defined (no significant differences in microbial contamination of different surfaces) and "high risk" objects not epidemiologically defined.

PROPERTIES OF AN IDEAL SURFACE DISINFECTANT

- Broad spectrum
- Fast acting
- Remains wet
- Not affected by environmental factors
- Nontoxic
- Surface compatibility
- Persistence
- Easy to use
- Acceptable odor
- Economical
- Solubility
- Stability
- Cleaner
- Nonflammable

Rutala WA, Weber DJ. Infect Control Hosp Epidemiol 2014;35:855-865

PROPERTIES OF AN IDEAL SURFACE DISINFECTANT

- Broad spectrum
  - Should have a wide antimicrobial spectrum, including kill claims for all pathogens that are common causes of HAIs and outbreaks
- Fast acting
  - Should have a rapid kill and short kill/contact time listed on the label
- Remains wet
  - Should keep surfaces wet long enough to meet listed kill/ contact times with a single application or meet wet times recommended by evidence-based guidelines (60 seconds)

Rutala WA, Weber DJ. Infect Control Hosp Epidemiol 2014;35:855-865

PROPERTIES OF AN IDEAL SURFACE DISINFECTANT

- Not affected by environmental factors
  - Should be active in the presence of organic matter (e.g., blood, sputum, feces) and compatible with soaps, detergents, and other chemicals encountered in use
- Nontoxic
  - Should not irritating to the user, visitors, and patients. Should not induce allergic symptoms (especially asthma and dermatitis). The toxicity ratings for disinfectants are danger, warning, caution, and none. Ideally choose products with the lowest toxicity rating.
- Surface compatibility
  - Should be proven compatible with common healthcare surfaces and devices

Rutala WA, Weber DJ. Infect Control Hosp Epidemiol 2014;35:855-865

PROPERTIES OF AN IDEAL SURFACE DISINFECTANT

- Persistence
  - Should have sustained antimicrobial activity or residual antimicrobial effect on the treated surface
- Easy to use
  - Should be available in multiple forms, such as wipes (large and small), sprays, pull tops, and refills; directions for use should be simple and contain information about personal protective equipment as required
- Acceptable odor
  - Should have an odor deemed acceptable by users and patients
- Solubility
  - Should be soluble in water

Rutala WA, Weber DJ. Infect Control Hosp Epidemiol 2014;35:855-865

PROPERTIES OF AN IDEAL SURFACE DISINFECTANT

- Economical
  - Costs should not be prohibitively high but when considering the costs of a disinfectant one should also consider product capabilities, cost per compliant use, etc.
- Stability
  - Should be stable in concentrate and use dilution
- Cleaner
  - Should have good cleaning properties
- Nonflammable
  - Should have a flash point above 150°F

Rutala WA, Weber DJ. Infect Control Hosp Epidemiol 2014;35:855-865

LOW-LEVEL DISINFECTION FOR NONCRITICAL EQUIPMENT AND SURFACES

Exposure time ≥ 1 min

Germicide	Use Concentration
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Chlorine	100ppm (1:500 dilution)
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UD=Manufacturer's recommended use dilution

Improve Environmental Disinfection Reduces HAIs

ARTICLE IN PRESS

American Journal of Infection Control xxx (2013) 1-8

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major article

Does improving surface cleaning and disinfection reduce health care-associated infections?

Curtis J. Donskey MD [a,b,*]

[a] Geriatric Research, Education, and Clinical Center, Cleveland Veterans Affairs Medical Center, Cleveland, OH
[b] Case Western Reserve University School of Medicine, Cleveland, OH

Key Words:
Environment
Cleaning
Transmission

Contaminated environmental surfaces provide an important potential source for transmission of health care-associated pathogens. In recent years, a variety of interventions have been shown to be effective in improving cleaning and disinfection of surfaces. This review examines the evidence that improving environmental disinfection can reduce health care-associated infections.

Does Improving Surface Cleaning and Disinfection Reduce Healthcare-Associated Infections?

Donskey CJ. AJIC. May 2013

"As reviewed here, during the past decade a growing body of evidence has accumulated suggesting that improvements in environmental disinfection may prevent transmission of pathogens and reduce HAIs. Although, the quality of much of the evidence remains suboptimal, a number of high-quality investigations now support environmental disinfection as a control strategy"

Alfa et al. AJIC 2015;43:141-146

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major article

Use of a daily disinfectant cleaner instead of a daily cleaner reduced hospital-acquired infection rates

Michelle J. Alfa PhD [a,b,*], Evelyn Lo MD [b,c], Nancy Olson BSc [a], Michelle MacRae [c], Louise Buelow-Smith RN [c]

[a] St Boniface Research Centre, Winnipeg, MB, Canada
[b] Department of Medical Microbiology, University of Manitoba, Winnipeg, MB, Canada
[c] St Boniface Hospital, Winnipeg, MB, Canada

Key Words:
Methicillin-resistant *Staphylococcus aureus*
Vancomycin-resistant enterococci
Clostridium difficile
Housekeeping
Environmental cleaning

Background: Documenting effective approaches to eliminate environmental reservoirs and reduce the spread of hospital-acquired infections (HAIs) has been difficult. This was a prospective study to determine if hospital-wide implementation of a disinfectant cleaner in a disposable wipe system to replace a cleaner alone could reduce HAIs over 1 year when housekeeping compliance was ≥80%.

Methods: In this interrupted time series study, a ready-to-use accelerated hydrogen peroxide disinfectant cleaner in a disposable wipe container system (DCW) was used once per day for all high-touch surfaces in patient care rooms (including isolation rooms) to replace a cleaner only. The HAI rates for methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), and *Clostridium difficile* were stratified by housekeeping cleaning compliance (assessed using ultraviolet-visible marker monitoring).

Results: When cleaning compliance was ≥80%, there was a significant reduction in cases/10,000 patient days for MRSA ($P = .0071$), VRE ($P < .0001$), and *C difficile* ($P = .0005$). For any cleaning compliance level there was still a significant reduction in the cases/10,000 patient days for VRE ($P = .0358$).

Conclusion: Our study data showed that daily use of the DCW applied to patient care high-touch environmental surfaces with a minimum of 80% cleaning compliance was superior to a cleaner alone because it resulted in significantly reduced rates of HAIs caused by *C difficile*, MRSA, and VRE.

Use of a Daily Disinfectant Cleaner Instead of a Daily Cleaner Reduced HAI Rates

Alfa et al. AJIC 2015.43:141-146

- Method: Improved hydrogen peroxide disposable wipe was used once per day for all high-touch surfaces to replace cleaner
- Result: When cleaning compliance was ≥ 80%, there was a significant reduction in cases/10,000 patient days for MRSA, VRE and *C. difficile*
- Conclusion: Daily use of disinfectant applied to environmental surfaces with a 80% compliance was superior to a cleaner because it resulted in significantly reduced rates of HAIs caused by *C. difficile*, MRSA, VRE

LOW-LEVEL DISINFECTION FOR NONCRITICAL EQUIPMENT AND SURFACES

Rutala, Weber, HICPAC, 2008, www.cdc.gov

Exposure time ≥ 1 min

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UD=Manufacturer's recommended use dilution

Sodium Hypochlorite

Rutala, Weber. Am J Infect Control 2013;41:S36-S41

ADVANTAGES

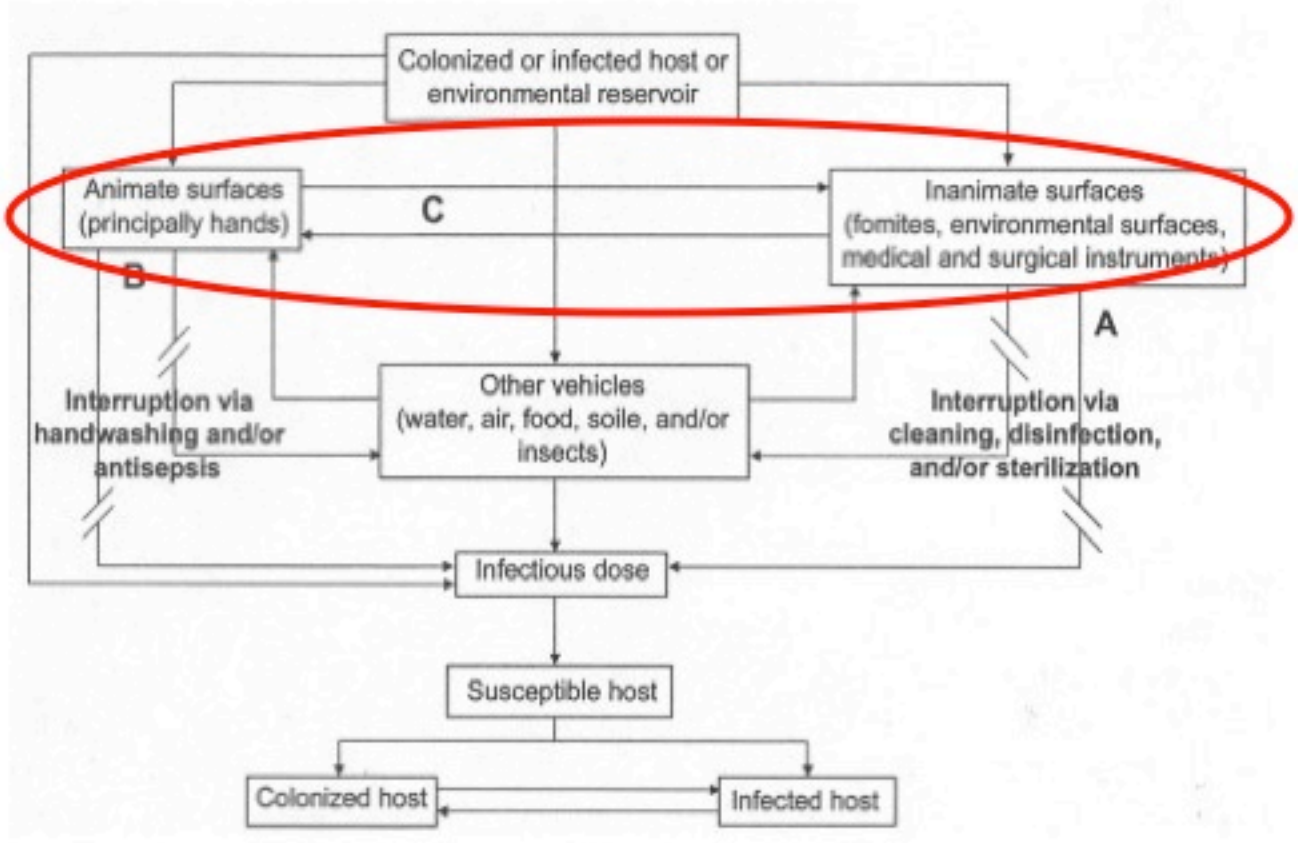
- Bactericidal, tuberculocidal, fungicidal, virucidal
- Sporicidal
- Fast acting
- Inexpensive (in dilutable form)
- Not flammable
- Unaffected by water hardness
- Reduces biofilms on surfaces
- Relatively stable (e.g., 50% reduction in chlorine concentration in 30 days)
- Used as the disinfectant in water treatment
- EPA registered

DISADVANTAGES

- Reaction hazard with acids and ammonias
- Leaves salt residue
- Corrosive to metals (some ready-to-use products may be formulated with corrosion inhibitors)
- Unstable active (some ready-to-use products may be formulated with stabilizers to achieve longer shelf life)
- Affected by organic matter
- Discolors/stains fabrics
- Potential hazard is production of trihalomethane
- Odor (some ready-to-use products may be formulated with odor inhibitors). Irritating at high concentrations.

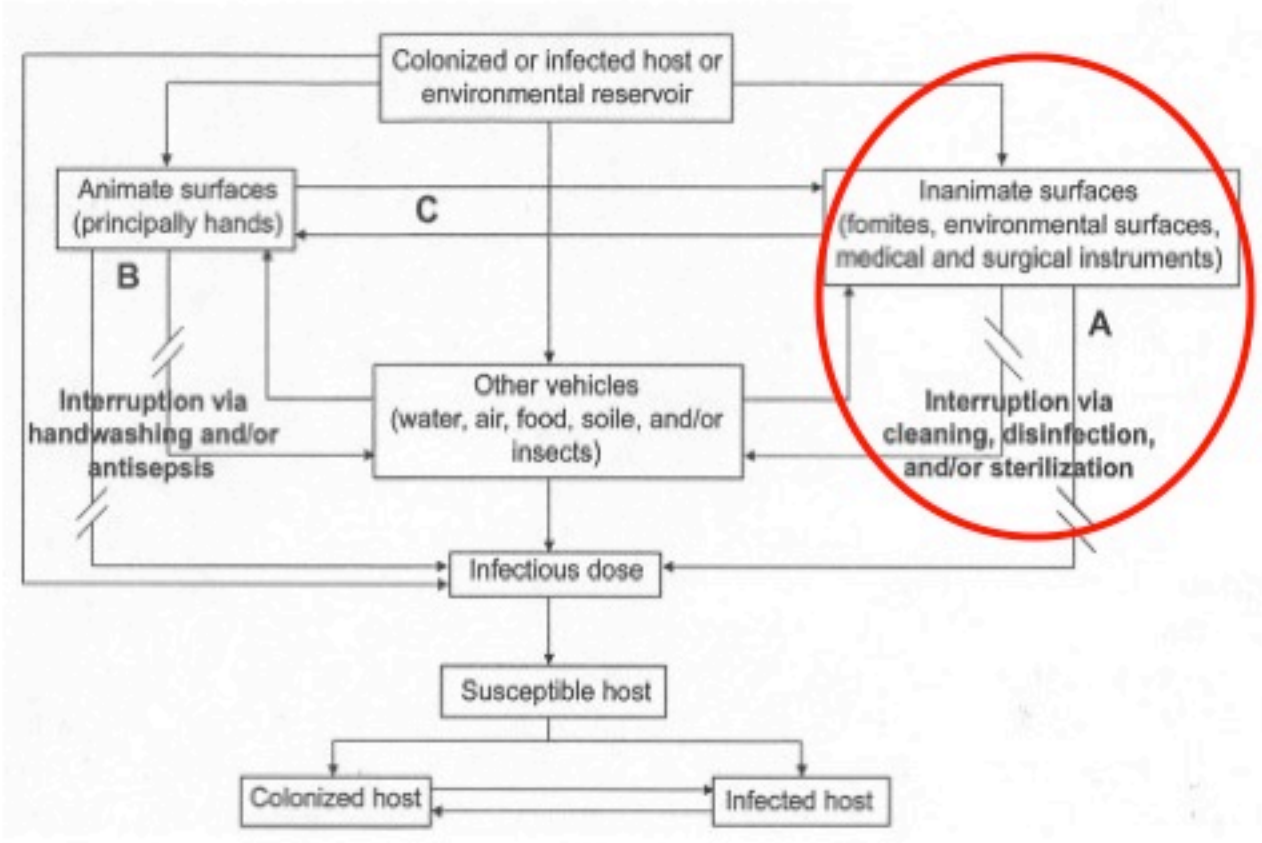
Controlling Pathogen Transmission in Healthcare Settings

TRANSMISSION MECHANISMS INVOLVING THE SURFACE ENVIRONMENT



Rutala WA, Weber DJ. In:"SHEA Practical Healthcare Epidemiology" (Lautenbach E, Woeltje KF, Malani PN, eds), 3rd ed, 2010.

TRANSMISSION MECHANISMS INVOLVING THE SURFACE ENVIRONMENT



Rutala WA, Weber DJ. In:"SHEA Practical Healthcare Epidemiology" (Lautenbach E, Woeltje KF, Malani PN, eds), 3rd ed, 2010.

Kill Claims for Most Prevalent Pathogens

- Each disinfectant requires a specific time it must remain in contact with the microbe to achieve disinfection. This is known as the kill time or contact time
- Some disinfectants may have a kill time for bacteria of 1m, which means bacteria in label disinfected in 1m
- Other low-level disinfectants, often concentrated formulas require dilution, are registered by the EPA with contact time of 10m
- Such a long contact time is not practical

Learning Objectives

Chemistry	Understand the science and technology behind sodium hypochlorite (bleach) cleaning and disinfecting products.
Antimicrobial Efficacy	Learn about sodium hypochlorite's antimicrobial mechanism of action.
Safety	Examine the facts related to sodium hypochlorite usage and safety.
Healthcare Applications	Understand how sodium hypochlorite is safely used today across Healthcare and in our Communities everyday to prevent the transmission of pathogens.

Part 1:

Sodium Hypochlorite - Chemistry

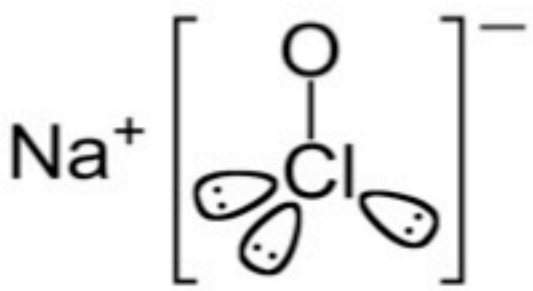
What is Sodium Hypochlorite?

Sodium hypochlorite is the active ingredient in *"Bleach"*

Bleach, by definition, lightens and /or whitens a substrate through a chemical reaction.

- Bleaching is commonly accomplished using ***oxidative chemistries like sodium hypochlorite***

Today, we will focus on **sodium hypochlorite** (NaOCl), the active ingredient in many household and institutional bleach products.



Bleach has played an important role in public health

there...

everywhere

The History of Sodium Hypochlorite

1854
Bleaching powder used to treat sewage in London

1869
Drinking water disinfection

1881
German bacteriologist, Koch demonstrates hypochlorite destroys bacteria

1913
Liquid sodium hypochlorite bleach is first introduced to commercial customers in US

1915
Sodium hypochlorite-based Dakin's solution developed and used during WWI to treat wounds and burns

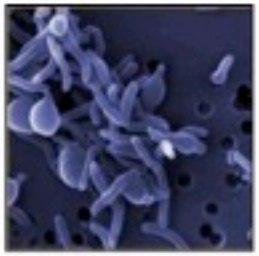
1960s
When the first Apollo flights were heading into space, NASA used bleach to decontaminate the capsules returning from orbit

1970s-1980s
Ready-to-use (RTU) bleach cleaning products introduced in North America

2000s
Widespread use of bleach to prevent *C. difficile* spread in healthcare settings

2014
Sodium hypochlorite recommended as part of Ebola-focused infection control protocols

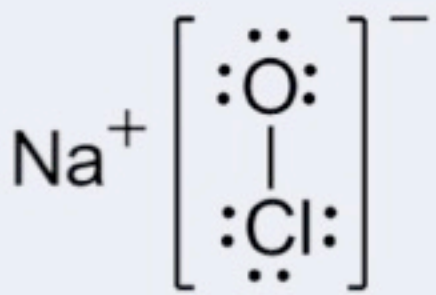
Common Uses of Sodium Hypochlorite ("Bleach")




Everyday Applications
Laundry
Sanitizing and disinfecting sinks, counters, floors in homes and institutional kitchens/ restaurants
Removing mold & mildew from floors, showers
Toilet bowl cleaners - cleaning and disinfecting
Drain cleaners
Disinfection of water in swimming pools, water treatment plants and natural wells
Textile and paper whitening

Healthcare Applications
Laundry
Cleaning and disinfecting environmental surfaces
Cleaning and disinfecting medical equipment
Cleaning and irrigating wounds
Endodontics (root canal irrigant)

Sodium Hypochlorite Chemistry

Common Names	Bleach "Chlorine" Bleach "Javex" "Clorox"
Molecular Formula	NaOCl or NaClO
Molecular Structure	
Acid Base Equilibrium (weak acid, pKa ~ 7.4) HOCl= hypochlorous acid	Sodium Hypochlorite $\rightleftharpoons$ Hypochlorous Acid $NaOCl + H^+ \Leftrightarrow HOCl + Na^+$ $HOCl + OH^- \Leftrightarrow H_2O + OCl^-$

Sodium Hypochlorite Chemistry

- **Sodium hypochlorite is typically produced using a 2-step process:**

1. **Electrolysis** (electrical current through salt water producing intermediates):
   $2\ NaCl + 2\ H_2O \rightarrow Cl_2 + H_2 + 2\ NaOH$

2. **Chlorine conversion** (intermediates react to form sodium hypochlorite):
   $Cl_2 + 2\ NaOH \rightarrow NaOCl + NaCl + H_2O$

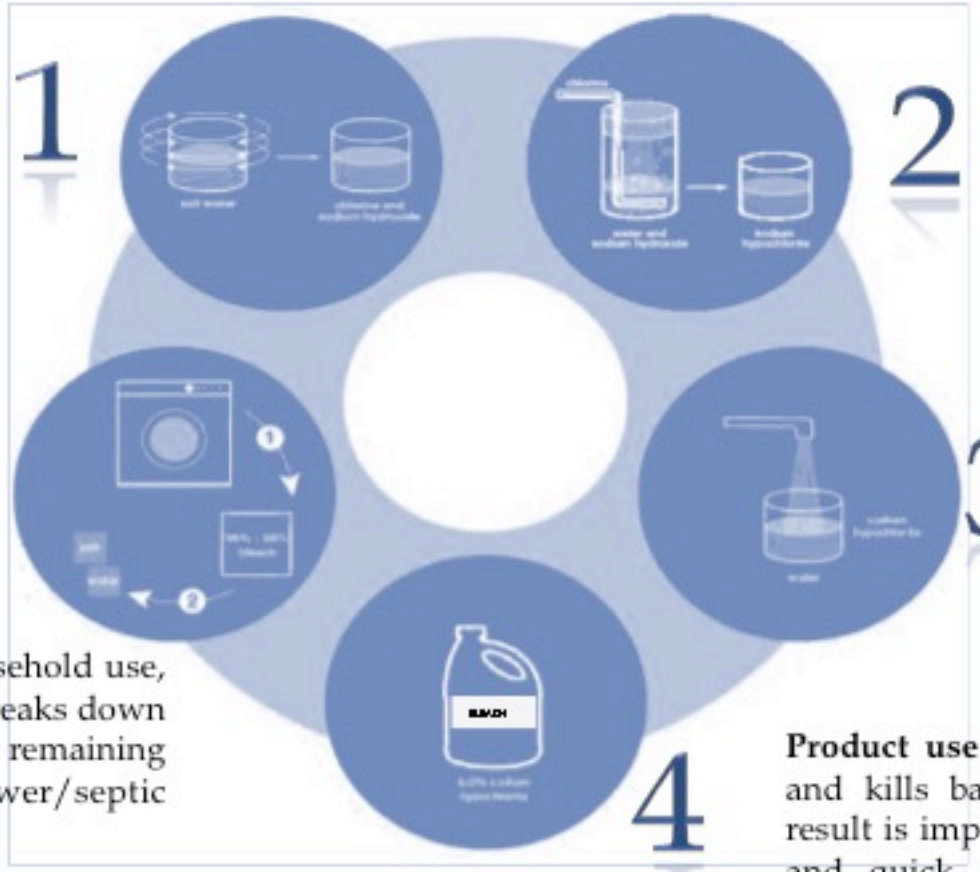
- **Bleach-based cleaners and disinfectants are water solutions of NaOCl that may also contain additives for enhanced cleaning and alkaline buffers for stability.**

"The Bleach Cycle"

Bleach begins and ends with Common Table Salt (NaCl)

Electrolysis: an electric current run through salt water produces chlorine and caustic (NaOH)

1



2

Chlorine conversion: Traditionally, household bleach is made by bubbling chlorine into a solution of water and caustic.

3

Bleach production: Sodium hypochlorite is diluted to specific concentrations with water.

4

Product use: Bleach breaks down soil and kills bacteria and viruses. The result is improved cleaning/whitening, and quick, effective and economical disinfecting.

5

Return to Salt: after household use, about 95-98% of bleach breaks down to salt and water. The remaining 2-5% is treated by sewer/septic systems.

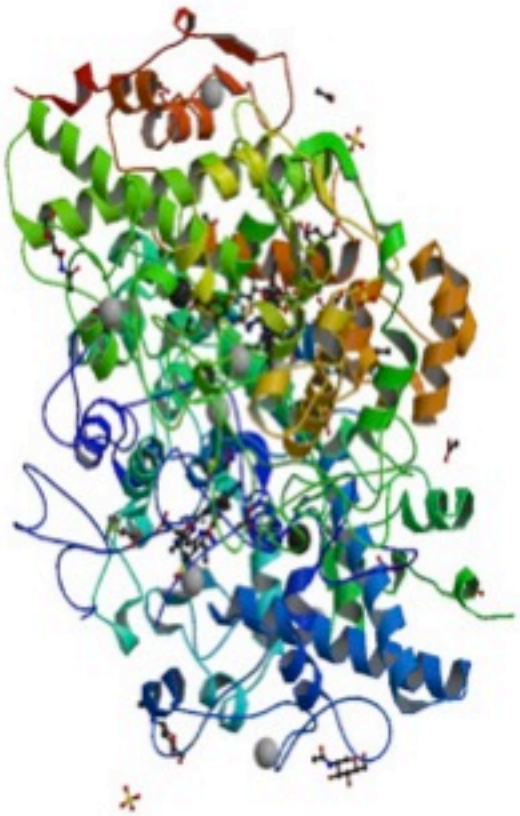
Part 2

Sodium Hypochlorite Antimicrobial Mechanism of Action and Efficacy

Hypochlorite Benefits

- **Antimicrobial:** a substance that kills or suppressed the growth of microorganisms such as bacteria, viruses, or fungi.

- **Hypochlorite is one of nature's antimicrobials!**
  - **Myeloperoxidase** generates *hypochlorous acid* in the human immune system
  - Seaweeds make hypohalous acid to prevent biofouling of leaves.
  - Fungal peroxidases make hypohalous acid to penetrate into hosts.



*Crystal structure of human myeloperoxidase**

*Blair-Johnson *et.al.*, Biochemistry, 2001, 40, 13990-13997.

How does sodium hypochlorite kill microorganisms?

Sodium hypochlorite has antimicrobial properties!

- The antimicrobial action of sodium hypochlorite solutions occur by:
  1. **disrupting protein** structure and function,
  2. **oxidative cell destruction**.

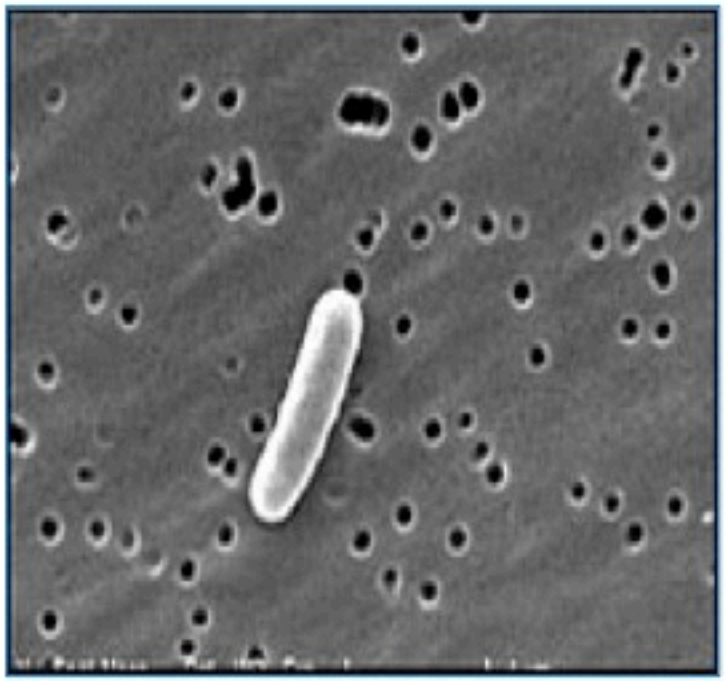
  - Sodium hypochlorite and hypochlorous acid, HOCl, are strong oxidizing agents which react with proteins and other biomolecules

$$NaOCl + H^+ \Leftrightarrow HOCl + Na^+$$

$$HOCl + OH^- \Leftrightarrow H_2O + OCl^-$$

- **Microbes do not develop resistance to sodium hypochlorite** due to the non-specific destruction of proteins and other cellular components.

A Closer Look at Oxidative Cell Destruction



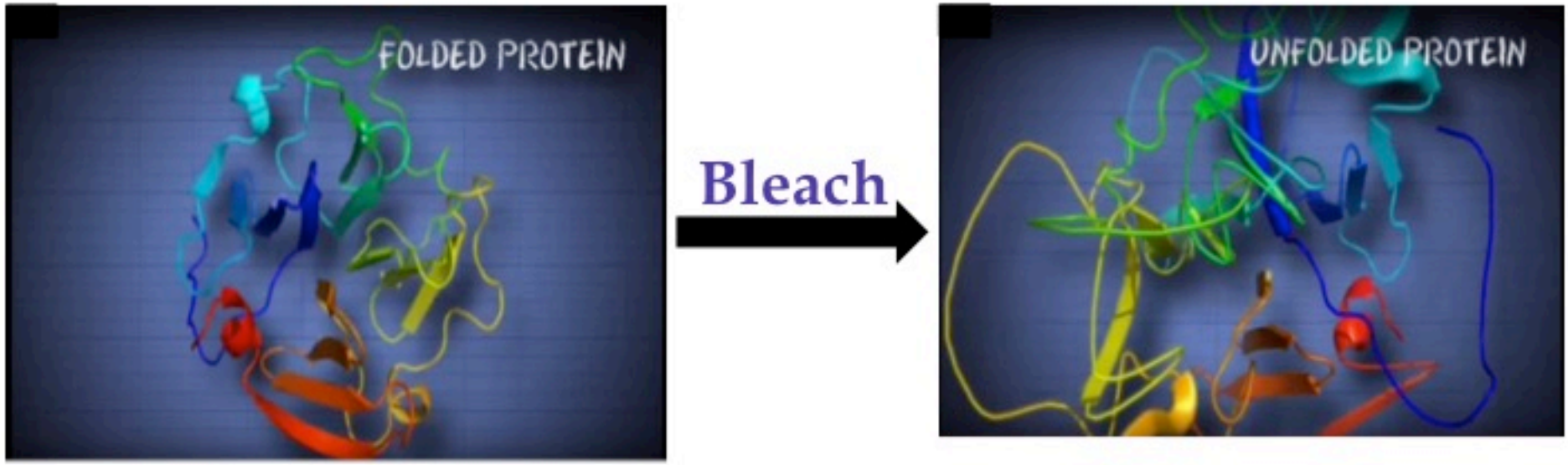
Typical *E.coli* Bacterium

Typical *E.coli* Bacterium
After Oxidation

Hypochlorites react with proteins, lipids, carbohydrates, DNA, RNA… virtually all biological molecules…. And oxidize them!

Why does Sodium Hypochlorite kill microbes quickly?

1. Bleach works quickly to oxidize proteins and unfold them.
2. Unfolded/oxidized proteins are targeted for additional reactions and ultimately cell death.[1]



1. Gray, M. J.; Wholey, W.-Y.; Jakob, U.*Annu. Rev. Microbiol.* **2013**, *67*, 141–160.

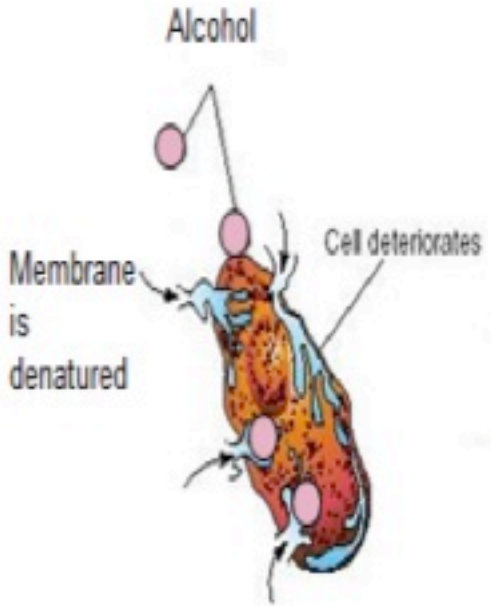
Comparison of Antimicrobial Mechanisms

Soaps and Detergents

Help to solubilize soils and aid in physical removal of debris and microbes.

Alcohol

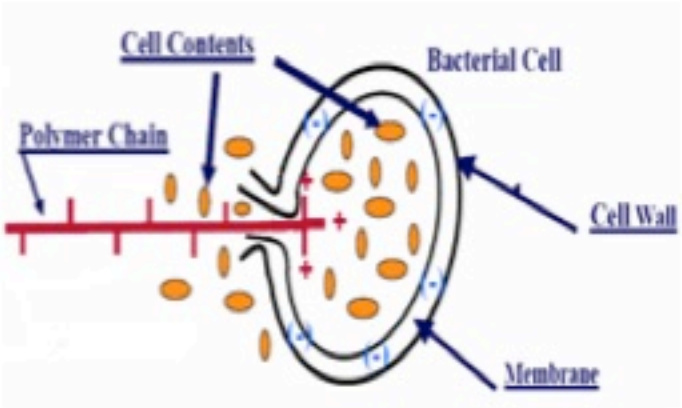
Denatures and dehydrates proteins



Comparison of Antimicrobial Mechanisms

Quaternary Ammonium Compounds (Quats)

Inactivate proteins and disrupt cell membrane

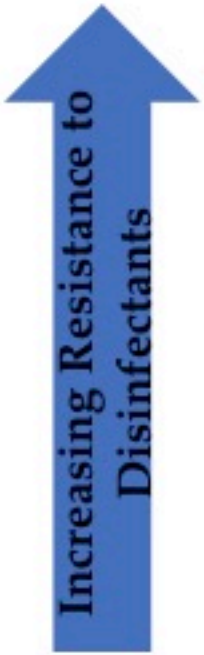


Oxidative Chemistries (i.e.. Sodium Hypochlorite)

Oxidize and unfold proteins, react with biomolecules and destroy cell structure.

How do sodium hypochlorite disinfectants stack up?

- Sodium hypochlorite has broad spectrum antimicrobial activity against a wide range of microorganisms.



Organism Class	Example
Spores	*C. difficile* spores
Mycobacteria	TB
Non-enveloped viruses	Norovirus
Fungi	*Candida albicans*
Vegetative Bacteria	*Staph* (MRSA)
Enveloped viruses	Influenza A Virus

Most Prevalent Pathogens Causing Healthcare-Associated Infections

Rutala, Weber. Infect Control Hosp Epidemiol. July 2014

- *Staphylococcus aureus* (15.6%)
- *E coli* (11.5%)
- Coagulase-negative *Staphylococcus* (CoNS) (11.4%)
- *Klebsiella* (8.0%)
- *Pseudomonas aeruginosa* (7.5%)
- *Enterococcus faecalis* (6.8%)
- *Candida albicans* (5.3%)
- *Enterobacter* spp. (4.7%)
- Other *Candida* spp. (4.2%)
- *Enterococcus faecium* (4.1%)
- *Enterococcus* spp. (3.0%)
- *Proteus* spp. (2.5%)
- *Serratia* spp. (2.1%)
- *Acinetobacter baumannii* (1.8%)

Modify Disinfectant Used

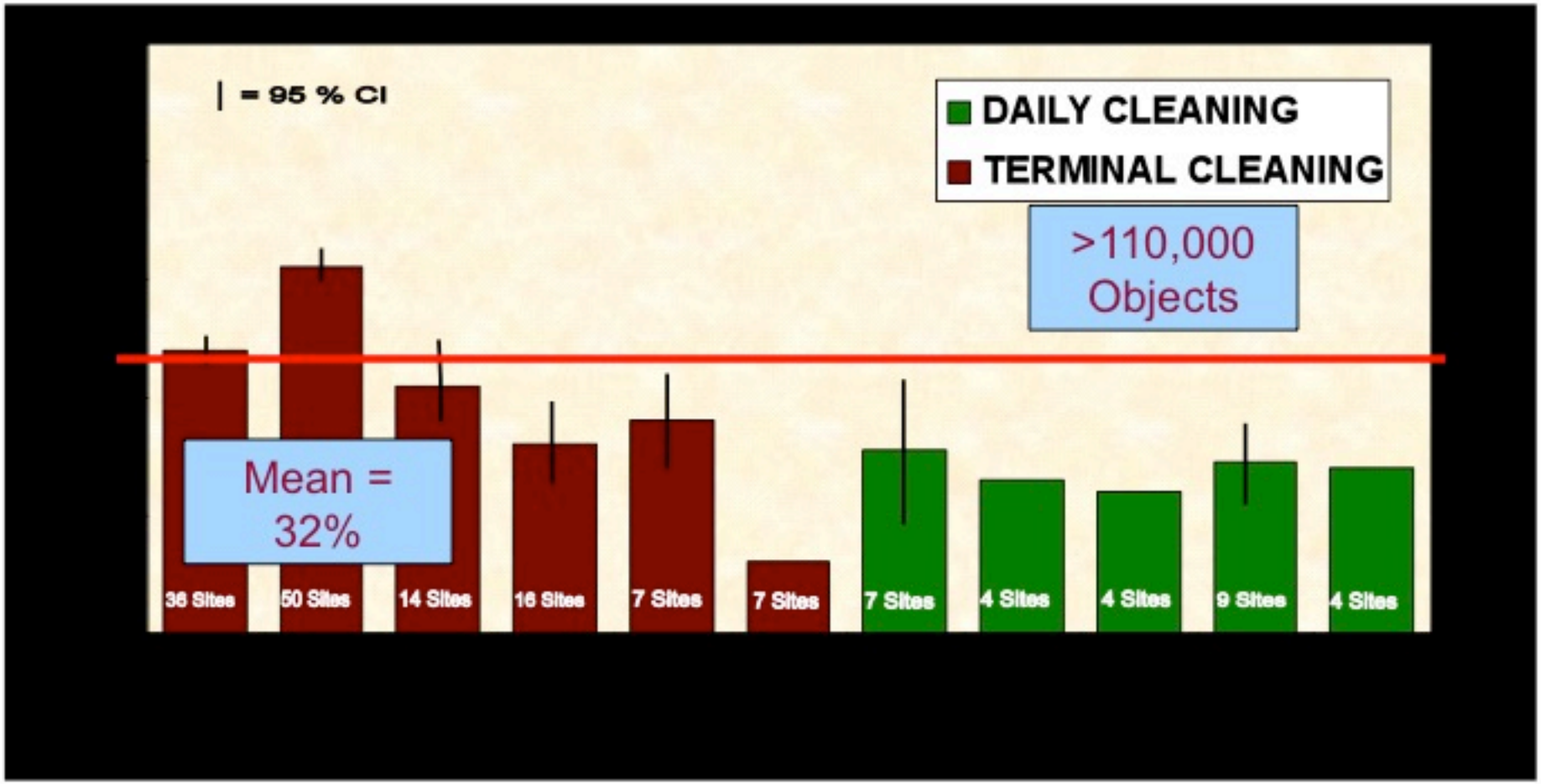
- ***C. difficile* spores-over the past decade, incidence of *C. difficile* increasing and now most common in some hospitals**
- **Norovirus**

EFFECTIVE SURFACE DECONTAMINATION

Product and Practice = Perfection

Thoroughness of Environmental Cleaning

Carling et al. Am J Infect Control. 2013;41:S20-S25



Wipes

Cotton, Disposable, Microfiber, Cellulose-Based, Nonwoven Spunlace

Wipe should have sufficient wetness to achieve the disinfectant contact time. Discontinue use of a disposable wipe if it no longer leaves the surface visibly wet for ≥ 1m

SURFACE DISINFECTION

Effectiveness of Different Methods

Technique (with cotton)	*C. difficile* Log_{10} Reduction (1:10 Bleach)
Saturated cloth	3.90
Spray (10s) and wipe	4.48
Spray, wipe, spray (1m), wipe	4.48
Spray	3.44
Spray, wipe, spray (until dry)	4.48
5500 ppm chlorine pop-up wipe	3.98
Non-sporicidal wipe	≥2.9

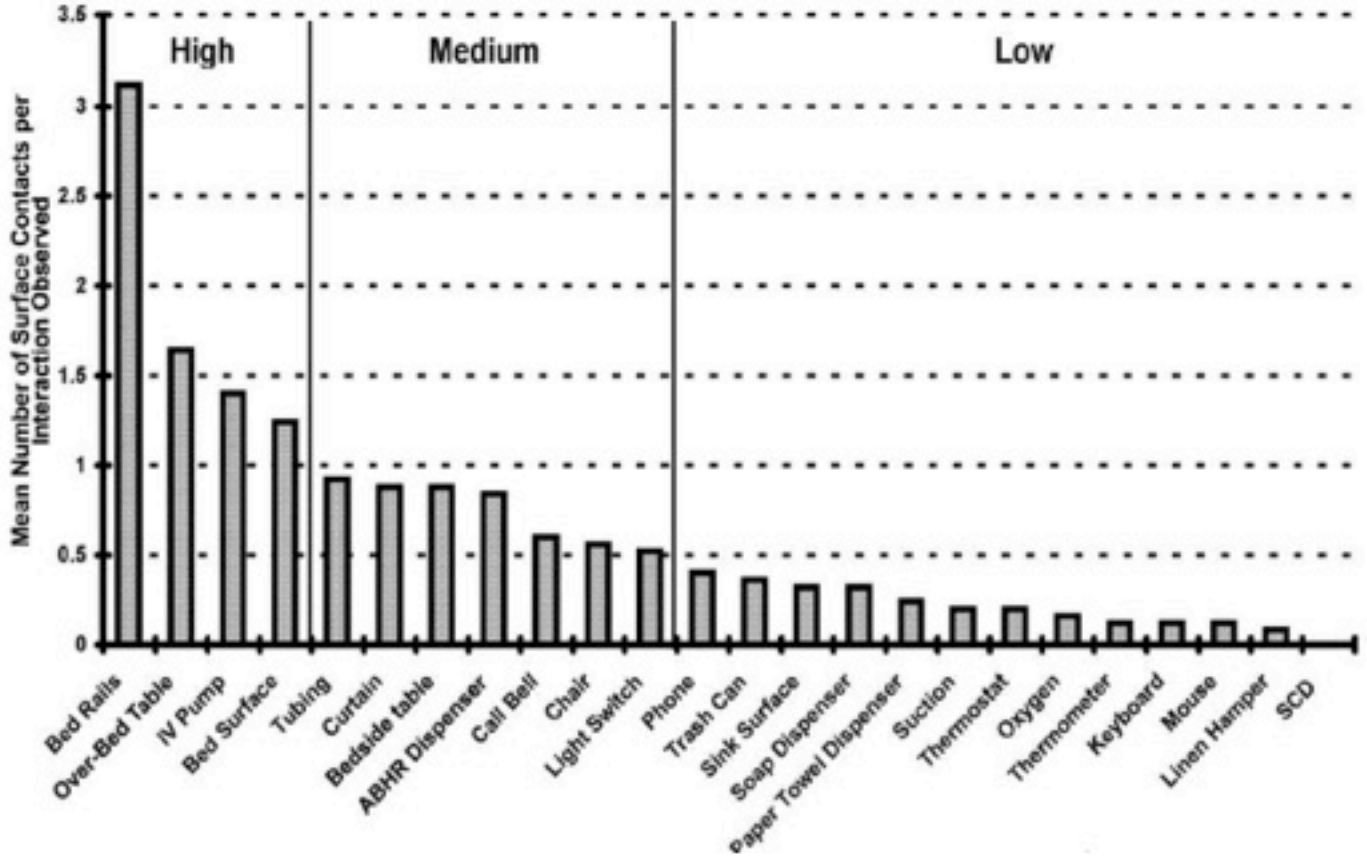
Rutala, Gergen, Weber. **ICHE 2012;33:1255-58**

ALL "TOUCHABLE" (HAND CONTACT) SURFACES SHOULD BE WIPED WITH DISINFECTANT

"High touch" objects only recently defined (no significant differences in microbial contamination of different surfaces) and "high risk" objects not epidemiologically defined.

DEFINING HIGH TOUCH SURFACES

Non-ICU



Huslage K, Rutala WA, Sickbert-Bennett E, Weber DJ. ICHE 2010;31:850-853

Microbiologic Assessment of High, Medium and Low Touch Surfaces

Huslage, Rutala, Gergen, Weber. ICHE 2013; 34:211

No correlation between touch frequency and microbial contamination

Surface	Before Cleaning Mean CFU/ Rodac	After Cleaning Mean CFU/ Rodac	Significance
High	71.9 (CI 46.5-97.3)	9.6	High=Low
Medium	44.2 (CI 28.1-60.2)	9.3	Medium=Low
Low	56.7 (CI 34.2-79.2)	5.7	

EFFECTIVENESS OF DISINFECTANTS AGAINST MRSA AND VRE

Rutala WA, et al. *Infect Control Hosp Epidemiol* 2000;21:33-38

TABLE 2
DISINFECTANT ACTIVITY AGAINST ANTIBIOTIC-SUSCEPTIBLE AND ANTIBIOTIC-RESISTANT BACTERIA

	Log_{10} Reductions							
	VSE		VRE		MSSA		MRSA	
Product	0.5 min	5 min	0.5 min	5 min	0.5 min	5 min	0.5 min	5 min
Vesphene IIse	>4.3	>4.3	>4.8	>4.8	>5.1	>5.1	>4.6	>4.6
Clorox	>5.4	>5.4	>4.9	>4.9	>5.0	>5.0	>4.6	>4.6
Lysol Disinfectant	>4.3	>4.3	>4.8	>4.8	>5.1	>5.1	>4.6	>4.6
Lysol Antibacterial	>5.5	>5.5	>5.5	>5.5	>5.1	>5.1	>4.6	>4.6
Vinegar	0.1	5.3	1.0	3.7	+1.1	+0.9	+0.6	2.3

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *S aureus*; VRE, vancomycin-resistant *Enterococcus*; VSE, vancomycin-susceptible *Enterococcus*.
Data represent mean of two trials (n=2). Values preceded by ">" represent the limit of detection of the assay. Assays were conducted at a temperature of 20°C and a relative humidity of 45%. Results were calculated as the log of Nd/No, where Nd is the titer of bacteria surviving after exposure and No is the titer of the control.

TABLE 1

EFFECTIVENESS OF DISINFECTANT AGAINST POTENTIAL PATHOGENS

	Log_{10} Reductions							
	Staphylococcus aureus		*Salmonella choleraesuis*		*Escherichia coli* O157:H7		*Pseudomonas aeruginosa*	
Product	**0.5 min**	**5 min**	**0.5 min**	**5 min**	**0.5 min**	**5 min**	**0.5 min**	**5 min**
Vesphene IIse	>8.2	>8.2	>6.7	>6.7	>6.6	>6.6	>6.7	>6.7
TBQ	>6.4	>6.4	>6.6	>6.6	>6.4	>6.4	>6.9	>6.2
Clorox	>5.8	>5.8	>5.9	>5.9	>5.6	>5.6	>5.3	>5.3
Ethanol	6.2	>6.7	>6.0	>6.0	>6.8	>6.8	>6.4	>6.4
Lysol Disinfectant	4.2	4.3	4.0	3.9	4.0	4.1	4.2	4.0
Lysol Antibacterial	>5.6	>5.6	>5.8	>5.8	>5.7	>5.7	>5.5	>5.5
Mr. Clean	4.1	>6.0	>5.7	>5.7	>6.1	4.7	>5.7	>5.7
Vinegar	0.03	0.3	>6.0	>6.0	0.4	2.4	>5.8	>5.8
Baking soda	0.2	0.5	2.3	2.3	0.4	0.7	1.1	1.1

Data represent mean of two replicates. Values preceded by ">" represent the limit of detection of the assay. Assays were conducted at a temperature of 20°C and a relative humidity of 45%. Results were calculated as the log of Nd/No, where Nd is the titer of bacteria surviving after exposure and No is the titer of the control.

Rutala WA, Barbee SL, Aguiar NC, Sobsey MD, Weber DJ. Antimicrobial Activity of Home Disinfectants and Natural Products Against Potential Human Pathogens. *Infection Control and Hospital Epidemiology* 2000;21:33-38.

Decreasing Order of Resistance of Microorganisms to Disinfectants/Sterilants

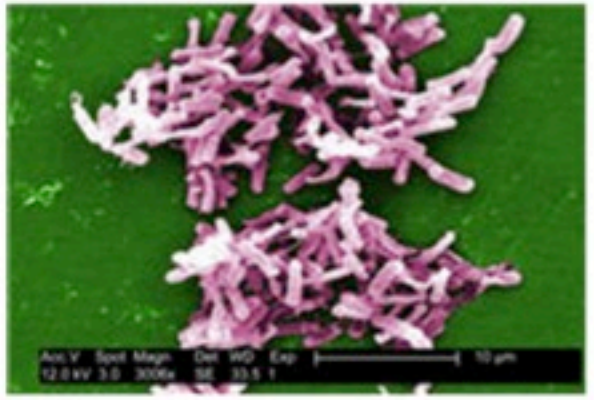
Most Resistant

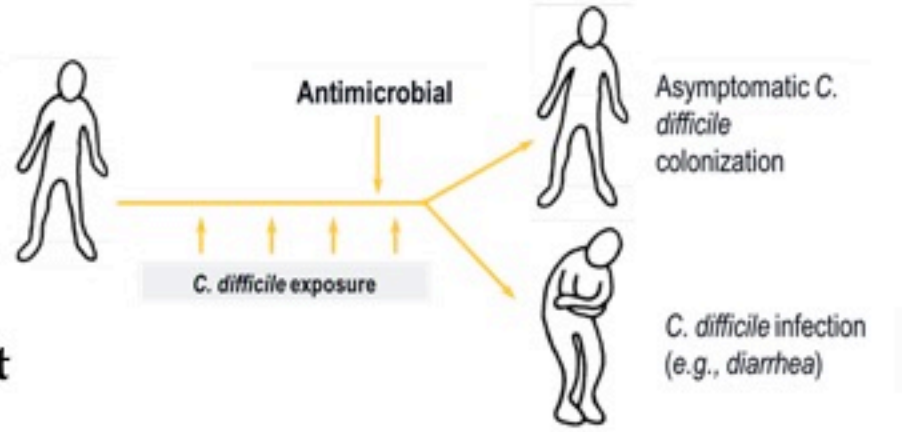
Most Susceptible

Prions
Bacterial spores (*C. difficile*)
Protozoal oocysts
Helminth eggs
Mycobacteria
Small, non-enveloped viruses (norovirus)
Protozoal cysts
Fungal spores
Gram-negative bacilli (*Acinetobacter*)
Vegetative fungi and algae
Large, non-enveloped viruses'
Gram-positive bacteria (MRSA, VRE)
Enveloped viruses

CLOSTRIDIUM DIFFICILE MICROBIOLOGY

- Anaerobic bacterium
- Forms spores that persist
- Colonizes human GI tract
- Fecal-oral spread
- Toxins produce colitis
  - Diarrhea
  - More severe disease; death
- 2-steps to infection
  - Antibiotics result in vulnerability
  - New acquisition via transmission
- CDI due to BI/NAP1/027 carries high mortality and management remains problematic





FREQUENCY OF ENVIRONMENTAL CONTAMINATION

- 25% (117/466) of cultures positive (<10 CFU) for *C. difficile*. >90% of sites positive with incontinent patients. (Samore et al. Am J Med 1996;100:32)
- 31.4% of environmental cultures positive for *C. difficile*. (Kaatz et al. Am J Epid 1988;127:1289)
- 9.3% (85/910) of environmental cultures positive (floors, toilets, toilet seats) for *C. difficile*. (Kim et al. J Inf Dis 1981;143:42)
- 29% (62/216) environmental samples were positive for *C. difficile*. 8% (7/88) culture-negative patient, 29% (11/38) positive cultures in rooms occupied by asymptomatic patients and 49% (44/90) in rooms with patients who had CDAD. (NEJM 1989;320:204)
- 10% (110/1086) environmental samples were positive for *C. difficile* in case-associated areas and 2.5% (14/489) in areas with no known cases. (Fekety et al. Am J Med 1981;70:907)
- 27% (13/48) of samples were positive for *C. difficile*. The NAP1 epidemic strain was found in 5 of 6 facilities. (Dubberke et al. AJIC 2007;35:315)

C. difficile Environmental Contamination

- Frequency ~10->50%-Stethoscopes, bed frames/ rails, call buttons, sinks, hospital charts, toys, floors, windowsills, commodes, toilets, bedsheets, scales, blood pressure cuffs, phones, door handles, electronic thermometers, flow-control devices for IV catheter, feeding tube equipment, bedpan hoppers
- *C. difficile* spore load is low; 7 studies assessed the spore load and most found <10 colonies on surfaces found to be contaminated. Two studies reported >100; one reported a range of "1->200" and one study sampled several sites with a sponge and found 1,300 colonies *C. difficile*.


Spore
www.amozeshonline.com/bacteriology

DISINFECTANTS AND ANTISEPSIS

C. difficile spores at 20 min, Rutala et al, 2006

- No measurable activity (1 *C. difficile* strain, J9)
  - CHG
  - Vesphene (phenolic)
  - 70% isopropyl alcohol
  - 95% ethanol
  - 3% hydrogen peroxide
  - Clorox disinfecting spray (65% ethanol, 0.6% QUAT)
  - Lysol II disinfecting spray (79% ethanol, 0.1% QUAT)
  - TBQ (0.06% QUAT); QUAT may increase sporulation capacity- Lancet 2000;356:1324
  - Novaplus (10% povidone iodine)
  - Accel (0.5% hydrogen peroxide)

Disinfectants and Antiseptics

C. difficile spores at 10 and 20 min, Rutala et al, 2006

- ~4 $\log_{10}$ reduction (5 *C. difficile* strains including BI-9)
  - Clorox, 1:10, ~6,000 ppm chlorine (but not 1:50, ~1,200 ppm)
  - Clorox Clean-up, ~19,100 ppm chlorine
  - Tilex, ~25,000 ppm chlorine
  - Steris 20 sterilant, 0.2% peracetic acid
  - Cidex, 2.4% glutaraldehyde
  - Cidex-OPA, 0.55% OPA
  - Wavicide, 2.65% glutaraldehyde
  - Aldahol, 3.4% glutaraldehyde and 26% alcohol

C. difficile Spores EPA-Registered Products

- List K: EPA's Registered Antimicrobials Products Effective Against *C. difficile* spores, April 2014
- http://www.epa.gov/oppad001/list_k_clostridium.pdf
- 34 registered products; most chlorine-based, some HP/PA-based, PA with silver

EPIDEMIOLOGICAL STUDIES WITH CHLORINE

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Major article

Does improving surface cleaning and disinfection reduce health care-associated infections?

Curtis J. Donskey MD [a,b,*]

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Key Words:
Environment
Cleaning
Transmission

Contaminated environmental surfaces provide an important potential source for transmission of health care-associated pathogens. In recent years, a variety of interventions have been shown to be effective in improving cleaning and disinfection of surfaces. This review examines the evidence that improving environmental disinfection can reduce health care-associated infections.

Contaminated environmental surfaces provide an important potential source for transmission of many health care associated pathogens.[1-6] These include *Clostridium difficile*, methicillin resistant infected with health care associated pathogens shed organisms onto their skin, clothing, bedding, and nearby environmental surfaces.[12] In addition to surfaces in rooms, portable equipment

Disinfectant Product Substitutions

Donskey CJ. AJIC. May 2013

Table 1
Studies involving disinfectant product substitutions

Ref	Setting and organism	Product	Practice	Monitoring of disinfection	Effect
31	2 Hospital wards Nosocomial infections	Active oxygen-based compound	Daily cleaning of oors and furniture	Cultures: decreased bacterial load on surfaces	No reduction in bloodstream infections or MRSA colonization or infection
32	Medical ward *Clostridium dif cile*	Hypochlorite 500 ppm	Terminal CDI rooms	Cultures: surface contamination decreased to 21% of initial levels	Outbreak ended
33	Bone marrow transplant (BMT) unit, Medical Ward, ICU *Clostridium dif cile*	Hypochlorite 5,000 ppm	Terminal CDI rooms	No	Signi cant decrease on BMT unit but not on the other 2 wards
34	2 Medical wards (crossover study) *Clostridium dif cile*	Hypochlorite 1,000 ppm	Terminal CDI rooms	Cultures: no decrease in the percentage of positive environmental cultures	Decreased on 1 of 2 wards
35	Medical and surgical ICUs *Clostridium dif cile*	Hypochlorite 5,000 ppm	Ward 1: terminal CDI rooms; ward 2: all rooms	No	Decreased on both units
36	3 Hospitals *Clostridium dif cile*	Hypochlorite 5,000 ppm	Terminal CDI rooms	No	48% decrease in prevalence density of CDI
25	2 Medical wards *Clostridium dif cile*	Hypochlorite 5,500 ppm (wipes)	Terminal and daily CDI and non-CDI rooms	Yes (ATP bioluminescence)	85% decrease in hospital acquired CDI

ATP, Adenosine triphosphate; *BMT*, Bone marrow transplant; *CDI*, *C dif cile* infection; *ICU*, intensive care unit; *PPM*, parts per million; *Ref*, reference number.
NOTE. 5,000 ppm 1:10 dilution of household bleach.

Disinfectant Product Substitutions

Donskey CJ. AJIC. May 2013

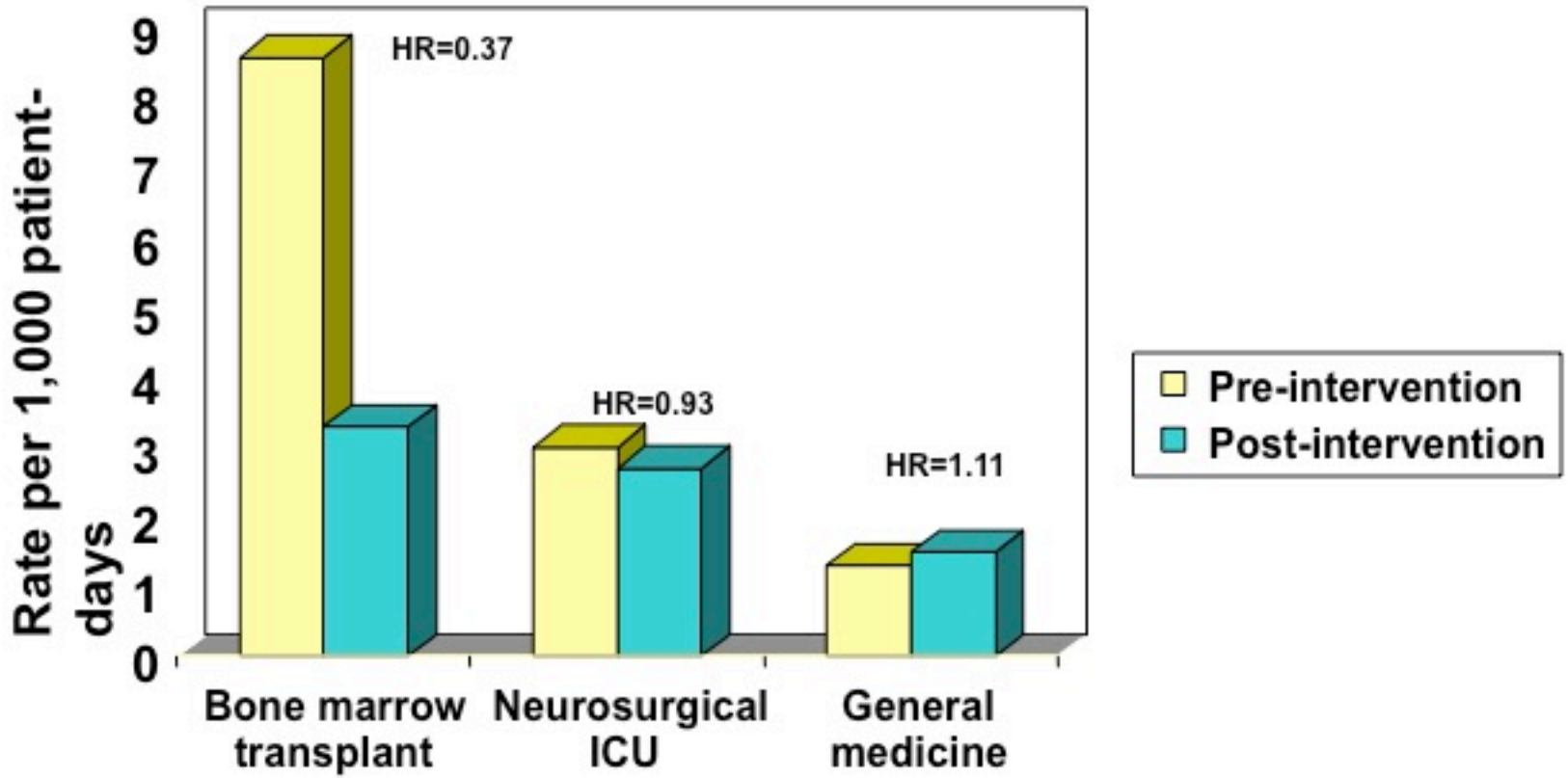
- Six of the 7 interventions were quasi-experimental studies in which rates were compared before and after interventions with no concurrent control group
- Confounding factors not reported (e.g., hand hygiene or Contact Precaution compliance)
- Decrease in the incidence in 6 of 7 studies

Substitution of Hypochlorite for Non-Sporicidal Cleaning Agents to Control *C. difficile*

Ref	Setting	Effect on CDI rates
1	Medical Ward	Outbreak ended
2	Bone marrow transplant (BMT) unit, Medical Ward, ICU	Significant decrease on BMT unit, but not on the other 2 wards
3	2 medical wards (crossover study)	Decreased on 1 of 2 wards
4	Medical and surgical ICUs	Decreased on both units
5	3 hospitals	48% decrease in prevalence density of CDI
6	2 medical wards	85% decrease in hospital acquired CDI

1). Katz G. Am J Epidemiol 1988;127:1289-94; 2). Mayfield JL. Clin Infect Dis 2000;31:995-1000; 3). Wilcox MH. J Hosp Infect 2003;54:109-114; 4). McMullen KM. Infect Control Hosp Epidemiol 2007;28:205-7; 5). Hacek DM. Am J Infect Control 2010;38:350-3; 6). Orenstein R. Infect Control Hosp Epidemiol 2011;32:1137-9

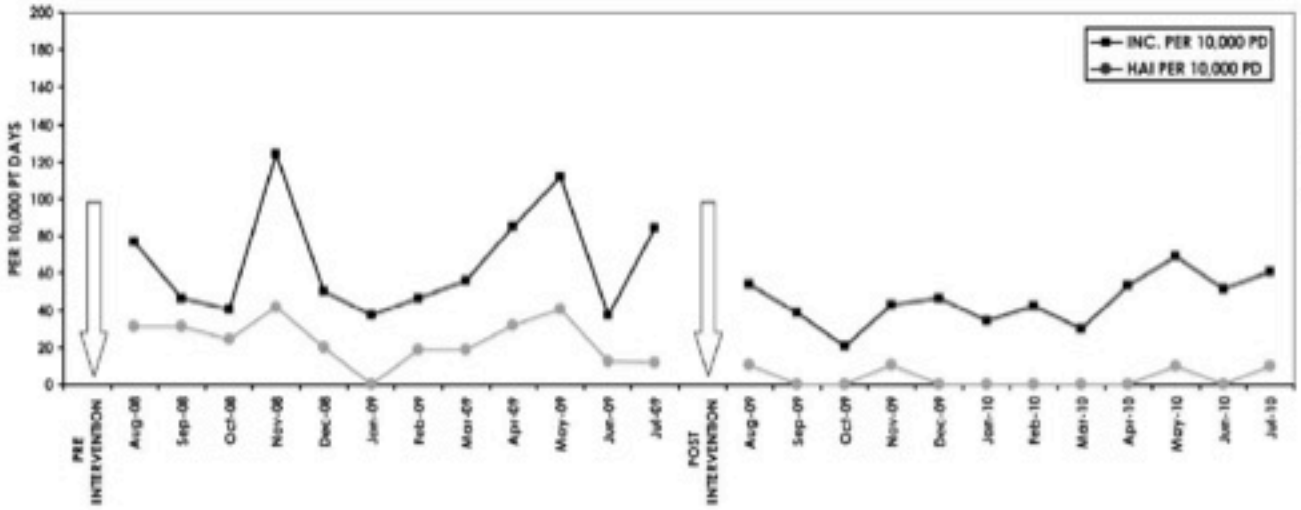
Effect of Environmental Disinfection with 10% Bleach on CDI Rates (results suggest greater impact when baseline incidence is high)



Mayfield JL, et al. Clin Infect Dis. 2000;31:995-1000

REDUCTION IN CDI INCIDENCE WITH ENHANCED ROOM DISINFECTION

- Before-after study of CDI incident rates in two hyperendemic wards at a 1,249 bed hospital
- Intervention: Change from cleaning rooms with QUAT to bleach wipes (0.55% Cl) for both routine and terminal disinfection
- Results
  - CDI incidence dropped from 24.2 to 3.6 cases per 10,000 pt-days ($p<0.001$)



Orenstein R, et al
ICHE 2011;32:1137

CONTROL MEASURES

C. difficile Disinfection

- In units with high endemic *C. difficile* infection rates or in an outbreak setting, use dilute solutions of 5.25-6.15% sodium hypochlorite (e.g., 1:10 dilution of bleach) or an approved-sporicidal product for environmental decontamination of rooms of patients with CDI. (Dubberke et al. SHEA 2014).
- We now use chlorine solution in all CDI rooms for routine daily and terminal cleaning. One application of an effective product covering all hand contact surfaces (chlorine not used on floors) to allow a sufficient wetness for > 1 minute contact time. Chlorine solution normally takes 1-3 minutes to dry.
- For semicritical equipment, glutaraldehyde (20m), OPA (12m) and peracetic acid (12m) kills *C. difficile* spores using normal exposure times

Transfer of *C. difficile* Spores by Nonsporicidal Wipes

Cadnum et al. ICHE 2013;34:441-2

- Detergent/nondisinfectant-nonsporicidal wipes transfer or spread microbes/spores to adjacent surfaces; disinfectants inactivate microbes

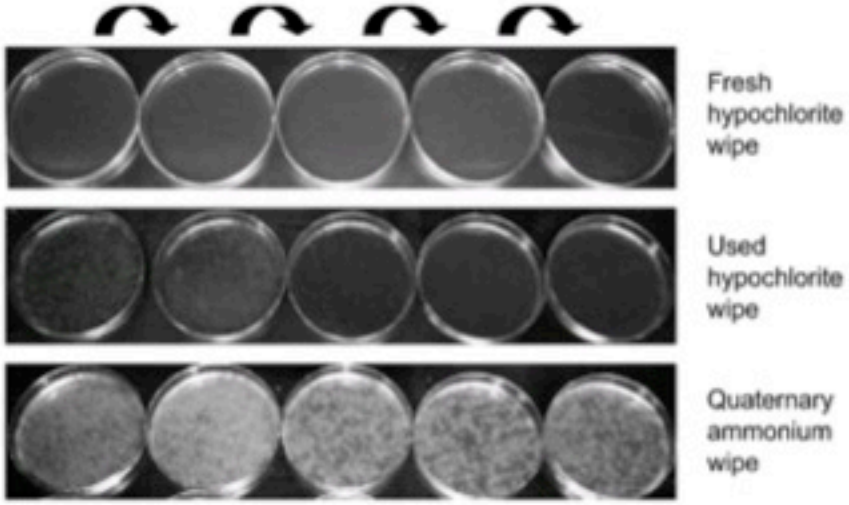


FIGURE 1. Illustration of transfer of *Clostridium difficile* spores by wipes. Ten-microliter aliquots containing ~5 $\log_{10}$ colony-forming units of spores were spread to cover a 1-cm^2 area and allowed to air dry. The inoculation site was manually wiped for 10 seconds with a wipe that was then sequentially wiped onto 4 clean sites for 10 seconds at each site. After 5 minutes of wet contact time, sites were sampled using a sterile premoistened cotton-tipped swab neutralising and serial dilutions were plated onto prereduced *C. difficile* Brucella agar. Experiments were performed in triplicate. A color version of this figure is available in the online edition of the journal.

Part 3

Safety-Clearing up Confusion about "Bleach" (NaOCl)

6 Common Bleach Concerns

1. Bleach contains chlorine gas
2. Bleach harms the environment
3. Bleach odor is unacceptable for staff and patients
4. Bleach causes respiratory irritation and asthma
5. Bleach causes cancer.
6. Using bleach will damage surfaces & equipment.

Occupational Health Risks Associated with Germicides

Weber, Consoli, Rutala AJIC 2016;44:e85

- Assessed use of germicides in healthcare facility associated with occupational health risk
- Evaluated injuries or illnesses caused by chemical exposures
- 2003-2012, UNC Hospitals employed 69,075 full-time work years, which constituted 144 million person days of exposures
- Overall, 128 chemical exposures , 70 caused by germicide (17 alcohol, 18 Quat, 12 not specified, glut 7, PA 6, hypochlorite 5, phenol 3, CHG 2)
- Dermatitis most common (antiseptics); splashes next most common; no episodes of acute bronchospasm or persistent asthma

Safety of Sodium Hypochlorite – Summary

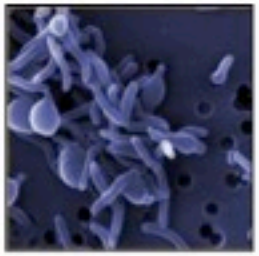
1. Bleach does not contain free chlorine.
2. When used as directed, the EPA has deemed currently available bleach products to be non-harmful to the environment.
3. Exposure to bleach and its by-products are usually innocuous.
   - If effects occur, they are minor, temporary irritations.
4. Hypochlorite has not been shown to be a sensitizer, carcinogen or cause reproductive toxicity.
5. Bleach is safe to use on many surfaces, and many issues may be avoided with proper residue management.

How to overcome perceived risks associated with bleach

- Select the right product for the right job
- Always use bleach products as directed
- Review product labels and safety data sheets (SDSs) prior to product use
- Evaluate study methodology as well as results from science-based resources (Beware of misinformation)

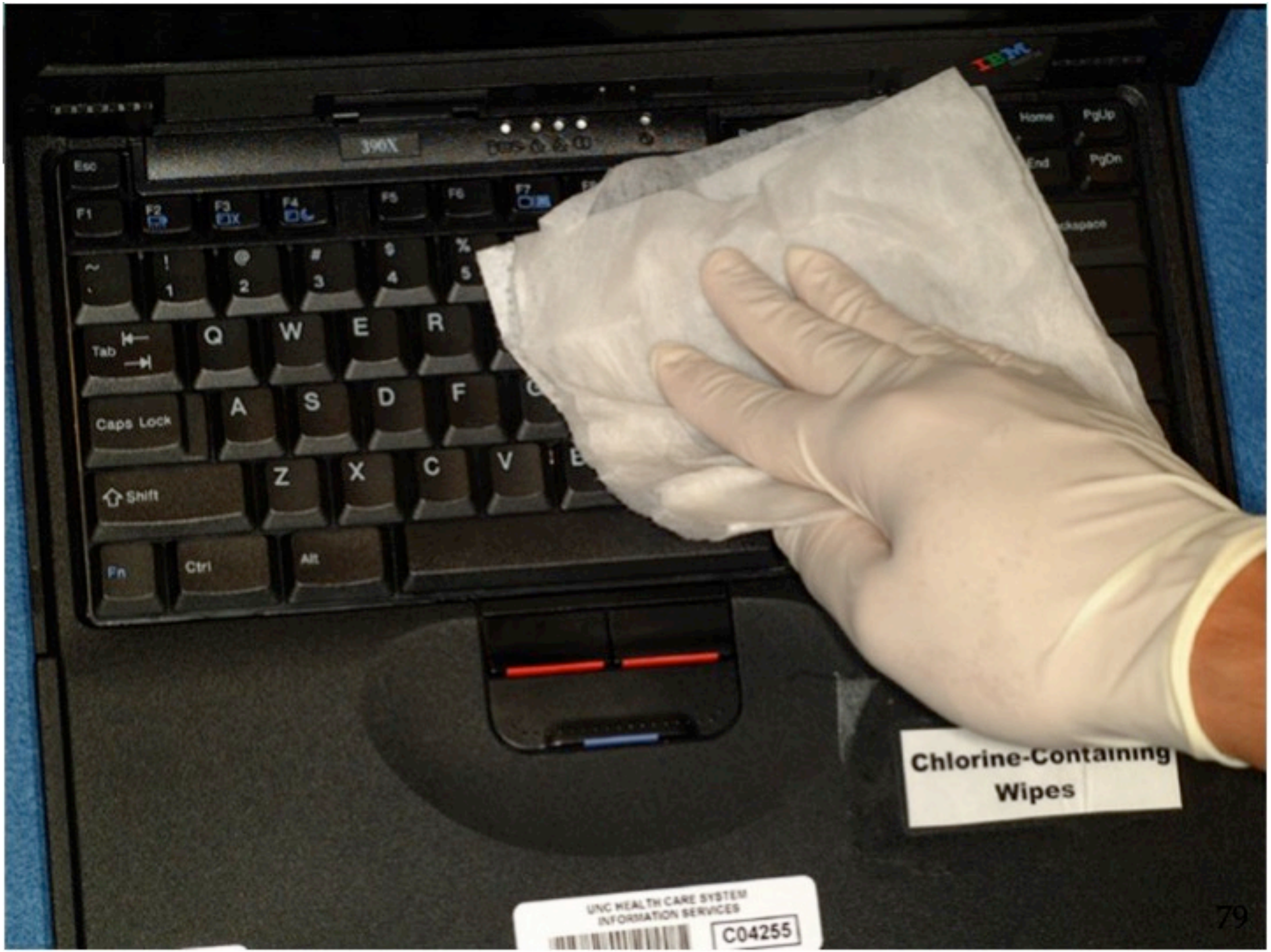
Part 4
Healthcare Applications

Common Uses of Sodium Hypochlorite ("Bleach")




Everyday Applications
Laundry
Sanitizing and disinfecting sinks, counters, floors in homes and institutional kitchens/ restaurants
Removing mold & mildew from floors, showers
Toilet bowl cleaners - cleaning and disinfecting
Drain cleaners
Disinfection of water in swimming pools, water treatment plants and natural wells
Textile and paper whitening

Healthcare Applications
Laundry
Cleaning and disinfecting environmental surfaces
Cleaning and disinfecting medical equipment
Cleaning and irrigating wounds
Endodontics (root canal irrigant)


Chlorine-Containing
Wipes
UNC HEALTH CARE SYSTEM
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Disinfection of Computer Keyboards

Rutala et al. ICHE 2006;27:372

- All tested products were effective (>95%) in removing and/or inactivating the test pathogens (MRSA, *P. aeruginosa*). No functional/cosmetic damage after 300 wipes.
- Disinfectants included: 3 quaternary ammonium compounds, 70% isopropyl alcohol, phenolic, chlorine (80ppm)
- At present, recommend that keyboards be disinfected daily (for 5 sec) and when visibly soiled

SURFACE DISINFECTION

Effectiveness of Different Methods

Technique (with cotton)	*C. difficile* Log_{10} Reduction (1:10 Bleach)
Saturated cloth	3.90
Spray (10s) and wipe	4.48
Spray, wipe, spray (1m), wipe	4.48
Spray	3.44
Spray, wipe, spray (until dry)	4.48
5500 ppm chlorine pop-up wipe	3.98
Non-sporicidal wipe	≥2.9

Rutala, Gergen, Weber. **ICHE 2012;33:1255-58**

Introducing New Healthcare Cleaner Disinfectant

- ✓ **Proven disinfecting power of bleach**
  - pH-neutral form of bleach
  - Kills *C. difficile* spores in 2 minutes (fastest kill time available*)
  - 35 other pathogens killed in 1 minute (bacteria, viruses, fungi)
- ✓ **Broad surface compatibility**
  - Leaves little to no residue on surfaces
  - Suitable for use on common healthcare surfaces – even clear plastics, glass and vinyl
- ✓ **Low odor**
  - Mild bleach odor disappears within 3-6 minutes
- ✓ **Easy to Use**
  - Ready to use, no mixing required
  - No PPE required
  - Advanced nozzle design delivers wider, more even spray coverage vs. traditional swirl nozzles

Effective against 36 pathogens

Bacteria – 1 minute
Acinetobacter baumannii
Burkholderia cepacia
Campylobacter jejuni
Carbapenem resistant Klebsiella pneumoniae
Enterobacter aerogenes
Enterobacter cloacae New Delhi Metallo-Beta Lactamase-1
Enterococcus faecalis
Escherichia coli O157:H7 [E. coli]
Klebsiella pneumoniae New Delhi Metallo-Beta Lactamase-1
Methicillin Resistant Staphylococcus aureus (MRSA)
Multi-drug resistant Staphylococcus aureus
Multi-drug Resistant Streptococcus pneumoniae
Multi-drug Resistant Enterococcus faecium
Mycobacterium bovis (TB)
Proteus mirabilis
Pseudomonas aeruginosa
Salmonella enterica
Serratia marcescens
Staphylococcus aureus
Staphylococcus epidermidis (CoNS)
Strenotrophomonas maltophilia
Vancomycin intermediate resistant Staphylococcus aureus (VISA)
Vancomycin Resistant Enterococcus faecalis (VRE)

Spores – 2 minutes
Clostridium difficile

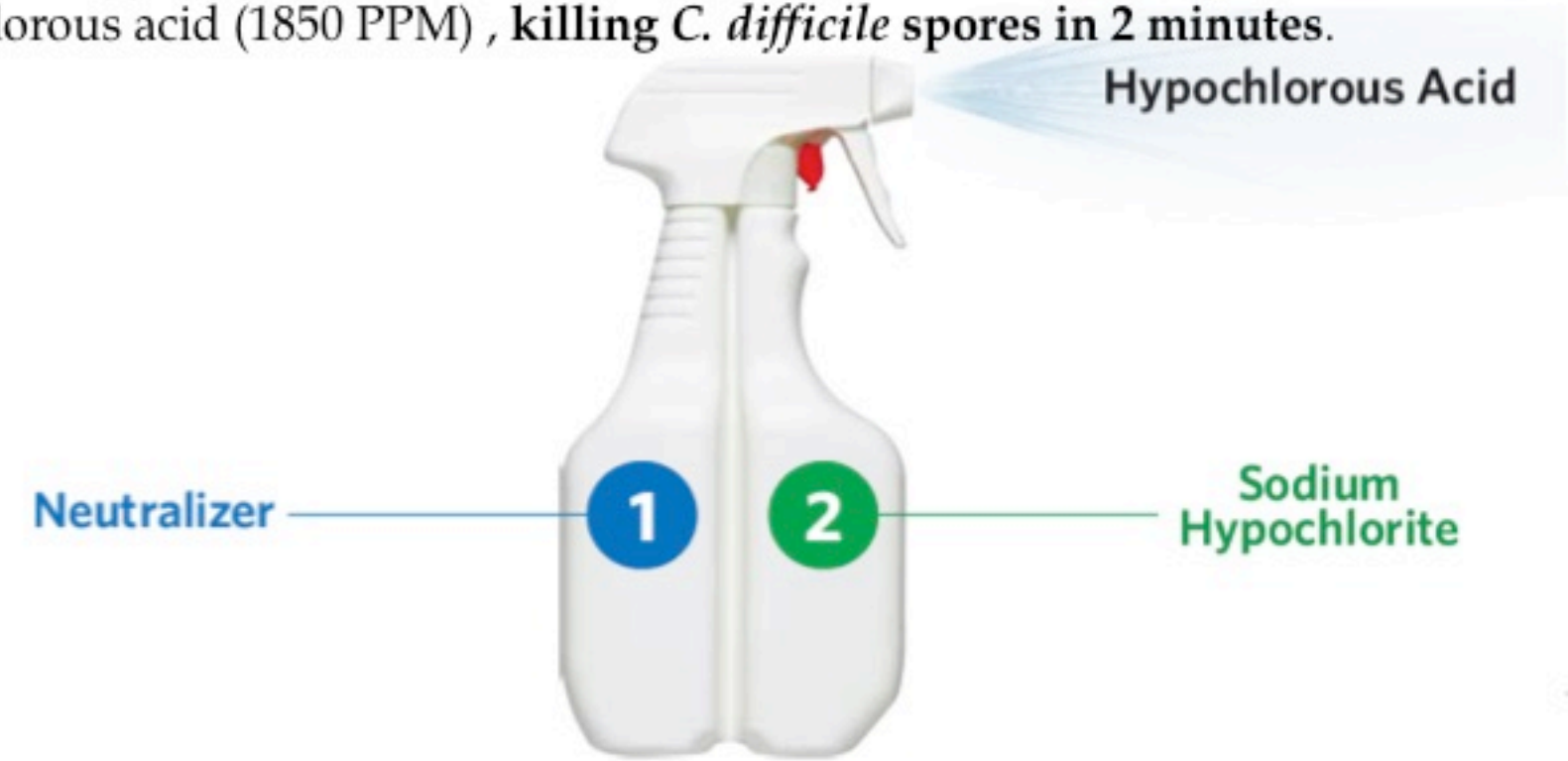
Viruses – 1 minute
[Enveloped]
Avian Influenza A (H5N1) virus
Hepatitis B Virus (HBV)
Herpes Simplex Virus Type I (HSV-1)
HIV Type 1
Human Coronavirus (RSV)
Influenza A virus (H1N1)
[Non-Enveloped]
Norovirus
Respiratory Syncytial Virus (RSV)
Rhinovirus
Rotavirus

Fungi – 1 minute
Candida Albicans
Trichophyton mentagrophytes [(Athlete's Foot Fungus)]

How does this new cleaner disinfectant work?

Cleaner Disinfectant is delivered via a dual-chamber trigger spray bottle. The first chamber holds a **3900 PPM bleach solution** (sodium hypochlorite). The second chamber has a **neutralizer** that consists of surfactants, a Self-Limiting Activated Sodium Hypochlorite (SLASH'ing) agent and a mild fragrance.

When the trigger spray is activated, the two components come together to form hypochlorous acid (1850 PPM) , **killing *C. difficile* spores in 2 minutes**.



Use on all patient rooms not just isolation rooms

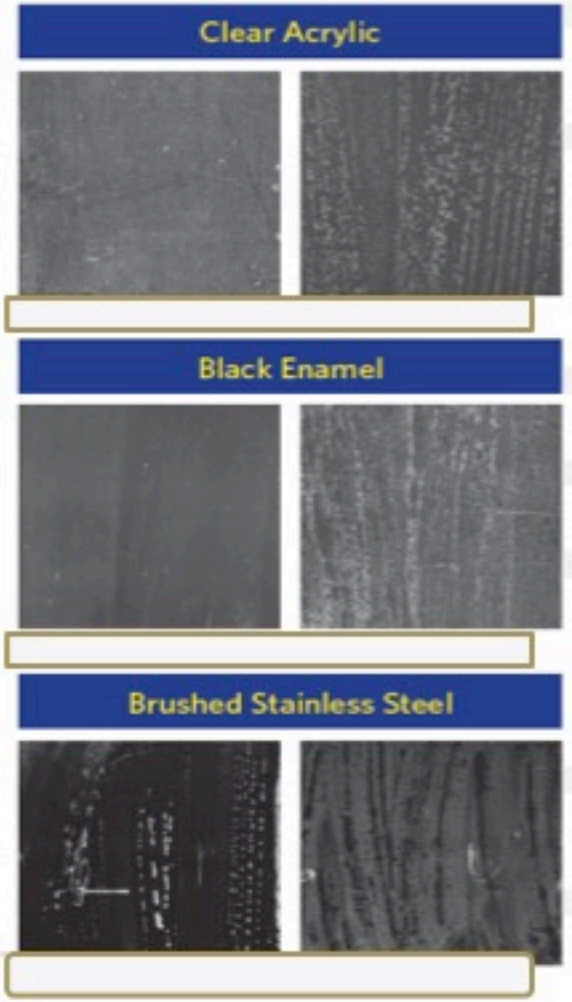
Now you can confidently eliminate *C. diff* on more surfaces than ever

Surface Compatibility + Low Residue = Opportunity to use Bleach Where You Need It

New cleaner disinfectant uses a new technology to eliminate the chemical reaction that can damage surfaces and leave a residue. Solution has a neutralizer that breaks down the bleach after a few minutes so water and a little sat is left. This minimizes residue and also corrosion because bleach is not staying on the surface. This allows you to use the new cleaner disinfectant on common healthcare surfaces.

New cleaner disinfectant leaves surfaces looking clean, not cloudy. Minimizing residue is important not only for maintaining surfaces but also for influencing patient perceptions of cleanliness. The figure on the right compares residue from the new cleaner disinfectant and a leading quat-alcohol disinfectant.

Residue on Common Healthcare Surfaces



* Based on laboratory testing prior to wiping with a damp cloth

Part 4

Bleach usage to prevent pathogen transmission

Environmental Cleaning and Disinfection Strategies

Product + Practice

Environmental Contamination Leads to HAIs

- Evidence environment contributes
- Role-MRSA, VRE, *C. difficile*
- Surfaces are contaminated-~25%
- EIP survive days, weeks, months
- Contact with surfaces results in hand contamination
- Disinfection reduces contamination
- Disinfection (daily) reduces HAIs
- Rooms not adequately cleaned

Summary

Chemistry	**Sodium hypochlorite is derived from table salt. Bleach does not contain free chlorine. Bleach degrades rapidly and completely during use and disposal.**
Antimicrobial Efficacy	**Bleach is one of the fastest and most effective disinfectants, rapidly oxidizing proteins and destroying microbes.** **Microbes do not develop resistance to bleach.**
Safety	**When used as directed in households and institutions, sodium hypochlorite-based products are safe and sustainable cleaners and disinfectants.**
Healthcare Applications	**Bleach has been used successfully in healthcare settings to reduce the transmission of HAI-causing pathogens including *Clostridium difficile*.**

LECTURE OBJECTIVES

- Review the role of the environment in transmission of nosocomial pathogens
- Review the properties of an ideal disinfectant
- Clarify bleach use in healthcare
  - Chemistry
  - Antimicrobial Efficacy
  - Safety
  - Healthcare Applications

Thank you for Slides

- **Sarah C. Bell-West, PhD,** Senior Scientist, Clorox Professional Products Company

Questions

info@webbertraining.com

THANK YOU!

www.disinfectionandsterilization.org

August 25 **APPLICATIONS AND LIMITATIONS OF DIPSLIDES AND PCR FOR REAL-TIME ENVIRONMENTAL CONTAMINATION EVALUATION**
Dr. Tobias Ibfelt, Copenhagen University Hospital, Denmark
Sponsored by Virox Technologies Inc, (www.virox.com)

September 15 **INFECTION CONTROL AND PET THERAPY**
Prof. Scott Weese, University of Guelph
Sponsored by Virox Technologies Inc, (www.virox.com)

September 22 **HARDWARE OR SOFTWARE? INTERVENTIONS FOR A SUSTAINABLE INFECTION CONTROL PROGRAM**
Prof. Joost Hopman, Radboud University, The Netherlands

September 26 *(Free Teleclass – Broadcast live from the IPS conference, UK)*
TO BE ANNOUNCED

September 28 *(Free Teleclass – Broadcast live from the IPS conference, UK)*
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