

Cleaning up Confusion about Bleach

Chemistry, Efficacy and Practical Applications in Healthcare Settings

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Disclosures

- ❑ Employee of The Clorox Company supporting the Clorox Healthcare business
- ❑ Chemist by education and training

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The Impact of HAIs in Canada

The Statistics

- *Healthcare Associated Infections (HAIs) contribute up to 50% of all hospital complications¹*
- *250,000 -330,000 Canadians/year will acquire an HAI^{2,3,5,6}*
- *Cause of 9,000 - 12,000 Canadian deaths annually^{2,3,4,5,6}*
- *1 in 9 hospital patients in Canada gets an HAI⁵*
- *Canadian attributable mortality rate 30 days after date of positive culture per 100 HA-CDI cases = 5.3*

Pathogen	cases/1000 patient admissions
<i>C. difficile</i>	5.35/1000 (PHAC 2011)
MRSA	9.49/1000 (PHAC 2009)
VRE	0.51/1000 (PHAC 2011)

1. Carling, P. C.; Parry, M. M.; Rupp, M. E.; Po, J. L.; Dick, B.; Von Beheren, S.; *Infect. Control Hosp. Epidemiol.* **2008**, 29 (11), 1035-1041.
2. *The Canadian Journal of Infection Control*. September 2008. Pages 152 & 154
3. Zoutman, DE, Ford DB, Bryce E et al. *Am J Infect Control*, 2003 ;31: 266-73.
4. Public Health Association of Canada- The Chief Public Health Officer's Report on the State of Public Health in Canada, 2013 <http://www.phac-aspc.gc.ca/cphorsphc-respcacsp/2013/infections-eng.php>
5. *Healthcare associated infections: A backgrounder*, January 2009, Canadian Union of Public Employees
6. *Hospital Acquired Infections in Canada and how to stop them*. Michael Hurley & Jonah Gindin, Ontario council of hospital unions (OCHU)

Controlling Pathogen Transmission in Healthcare Settings



Learning Objectives

Chemistry

Understand the science and technology behind sodium hypochlorite 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

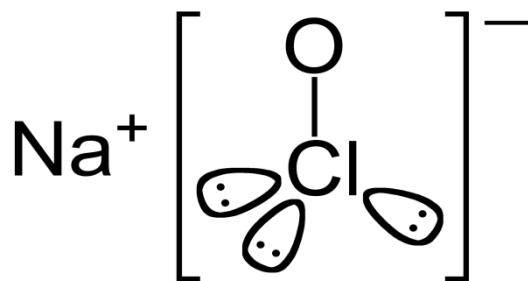
What is Sodium Hypochlorite?

Sodium hypochlorite is the active ingredient in “*Bleach*”

Bleach, by definition, lightens &/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



The History of Sodium Hypochlorite

1854

Bleaching powder used to treat sewage in London

1881

German bacteriologist, Koch demonstrates hypochlorite destroys bacteria

1915

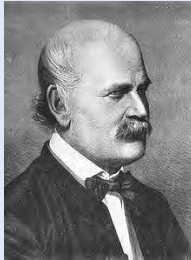
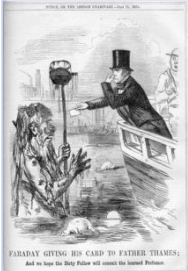
Sodium hypochlorite-based Dakin's solution developed and used during WWI to treat wounds and burns

1970s-1980s

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

2014

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



1869

Drinking water disinfection

1913

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

1960s

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

2000s

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

Common Uses of Sodium Hypochlorite ("Bleach")



Everyday Applications

Laundry

Sanitizing & 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 & paper whitening

Healthcare Applications

Laundry

Cleaning & disinfecting environmental surfaces

Cleaning and disinfecting medical equipment

Cleaning and irrigating wounds

Endodontics
(root canal irrigant)

Sodium Hypochlorite Chemistry

<p>Common Names</p>	<p>Bleach "Chlorine" Bleach "Javex" "Clorox"</p>
<p>Molecular Formula</p>	<p>NaOCl or NaClO</p>
<p>Molecular Structure</p>	$\text{Na}^+ \left[\begin{array}{c} \text{:}\ddot{\text{O}}\text{:} \\ \\ \text{:}\ddot{\text{Cl}}\text{:} \end{array} \right]^-$
<p>Acid Base Equilibrium (weak acid, pKa ~ 7.4) HOCl= hypochlorous acid</p>	<p>Sodium Hypochlorite \rightleftharpoons Hypochlorous Acid</p> $\text{NaOCl} + \text{H}^+ \rightleftharpoons \text{HOCl} + \text{Na}^+$ $\text{HOCl} + \text{OH}^- \rightleftharpoons \text{H}_2\text{O} + \text{OCl}^-$

Sodium Hypochlorite Chemistry

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

1. **Electrolysis:**



2. **Chlorine conversion:**



- 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)



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



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



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

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



- 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

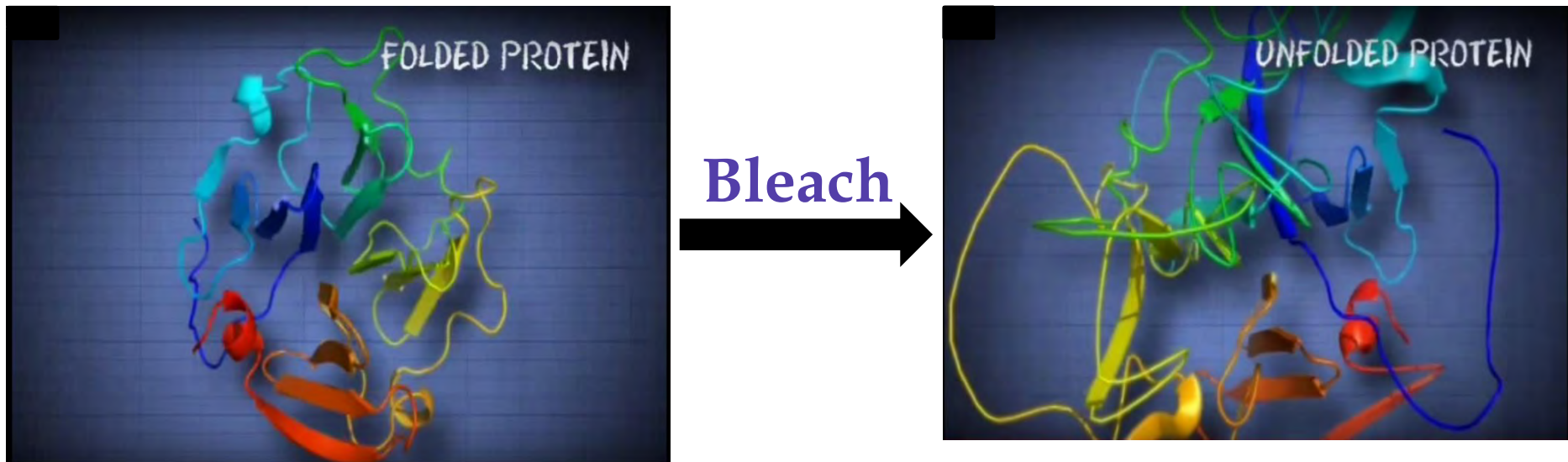


Typical *E.coli* Bacterium
After Oxidation

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



Comparison of Antimicrobial Mechanisms

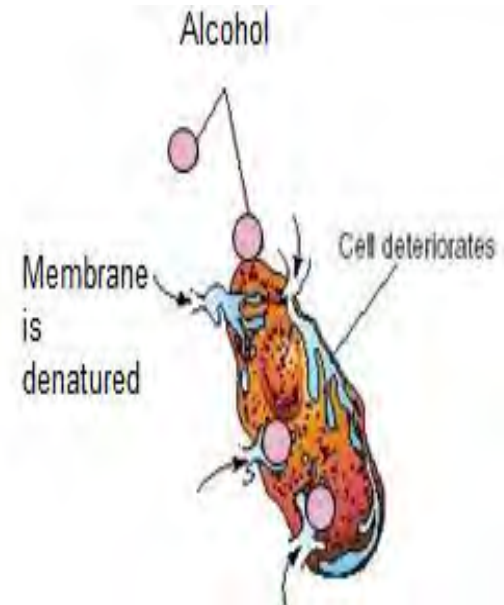
Soaps and Detergents

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



Alcohol

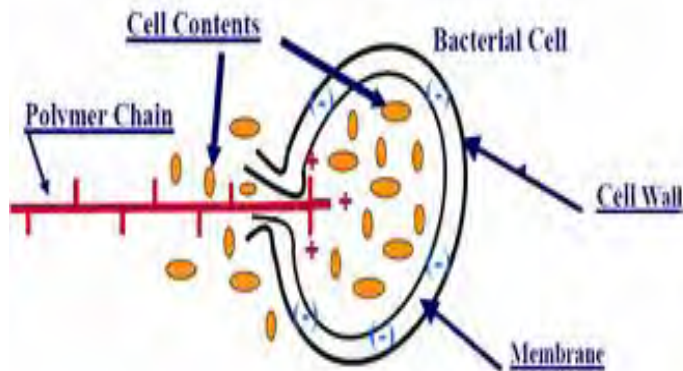
Denatures and dehydrates proteins



Comparison of Antimicrobial Mechanisms

Quaternary Ammonium Compounds (Quats)

Inactivate proteins and
disrupt cell membrane



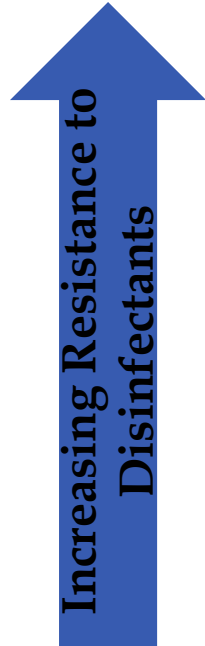
Oxidative Chemistries (i.e.. Sodium Hypochlorite)

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	<i>C. difficile</i> spores
Mycobacteria	TB
Non-enveloped viruses	Norovirus
Fungi	<i>Candida albicans</i>
Vegetative Bacteria	<i>Staph</i> (MRSA)
Enveloped viruses	Influenza A Virus

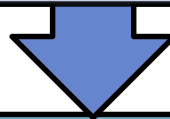
Hypochlorite inactivates proteins that cause allergies

The Allergic Response

- An allergen is a small protein that triggers an immune response.
 - Pet dander, dust mite matter, and pollen are common allergen-containing particles.

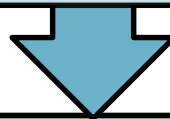
Sensitization

Over time, the immune system identifies the allergen as an invader and develops antibodies called Immunoglobulin E (IgE).



Re-exposure

When an individual is again exposed to the allergen, these antibodies bind to the small protein and carried it to other immune cells, which release chemicals.



Allergy Symptoms

One of these chemicals is called histamine and, it is responsible for many of the symptoms that asthmatics experience such as coughing, wheezing and difficult breathing.

Hypochlorite inactivates proteins that cause allergies

Efficacy of bleach vs. various allergens

- The table below demonstrates the efficacy of Clorox® Clean-Up® Cleaner + Bleach spray, a sodium hypochlorite-based disinfectant, in the inactivation of various allergens vs. the non-bleach-based competitive set.*

Products	Type: Der p1 Dust Mite Matter	Type: Der p2 Dust Mite Matter	Type: Fel d1 Cat Dander	Type: Can f1 Dog Dander
Allergen »	Reduction	Reduction	Reduction	Reduction
Clorox® Clean-Up® Spray, 3 minutes	99%	96%	>99%	>99%
Other Spray Cleaners (10 minute)				
Lysol® Antibacterial Kitchen Cleaner	28%	20%	2%	1%
Lysol® Lemon All-Purpose Cleaner	31%	5%	0	2%
Lysol® Basin, Tub & Tile Cleaner	97%	0	0	0
Disinfecting Sprays				
Lysol® Disinfecting Spray	99%	64%	11%	22%

*Data generated internally by Clorox scientists

Part 3

Cleaning 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.

Common Bleach Concerns

#1 Bleach contains Chlorine Gas

Although referred to as “Chlorine Bleach” there is no free elemental chlorine (Cl₂) in bleach.

- Both sodium hypochlorite (NaOCl) and sodium chloride (NaCl) contain chlorine atoms (Cl).
- Sodium hypochlorite production process results in complete conversion.



Under normal use and following labeling instructions, bleach does not produce chlorine gas.

Common Bleach Concerns

#2 Bleach harms the Environment

- ❑ Sodium hypochlorite degrades rapidly and completely during use.
- ❑ It reacts with organic materials and quickly breaks down, mainly into salt & water.
- ❑ Any residual byproducts are treated in water treatment plants.
- ❑ Dioxins are not formed during the manufacture, storage or household/institutional uses of bleach.
- ❑ The EPA has concluded that the “currently registered uses of the hypochlorites will not result in unreasonable adverse effects to the environment.”¹



1. EPA R.E.D. Facts Sodium and Calcium Hypochlorite Salts September 1991.

Common Bleach Concerns

#3 Bleach odor is unacceptable

- ❑ The characteristic smell of bleach should not be the cause for concern for any adverse health effects.
- ❑ Sodium hypochlorite has no actual odor, as it is not volatile.
- ❑ The “bleach smell” comes from the interaction of bleach with organic mater. The more soil the stronger the smell.
 - Bleach’s odor is caused by the chemical reactions that occur when bleach begins to break down proteins.



Common Bleach Concerns:

#3 Bleach odor is unacceptable...

Steps to mediate bleach odor concerns

- Always read and follow product label instructions before use
- Do not use or mix bleach with other cleaners
- Ensure adequate ventilation in areas where bleach is used
- Remove gross filth prior to using bleach for cleaning and disinfection
- Consider regular use of bleach to minimize build-up of organic matter, mold or other microbes

Common Bleach Concerns

#4 Bleach causes Asthma

Many chemicals or odors can be irritants if they are present in high enough concentrations.

- ❑ If an irritant is strong enough – it can trigger an asthmatic response in individuals who do have asthma – or it can trigger symptoms which mimic asthma.
- ❑ At *elevated concentrations*, some chemicals can produce respiratory tract irritation which can result in asthma-like symptoms.
 - In the case of exposure to concentrated bleach and/or product misuse (bleach mixed with acids), exposure can result in asthma-like symptoms.

Common Bleach Concerns:

#4 Bleach causes Asthma

Separating out asthma from respiratory irritation can be difficult

- There are numerous studies in the literature that suggest a link between regular use of bleach and asthma and/or asthma-type symptoms.¹

Application	Author conclusions ²	Reference
Regular use of bleach for cleaning	<i>“cleaners who used bleach almost daily had a significant increase in risk of developing asthma.”</i>	Medina-Ramon et al, 2005 ²

- Closer examination of the methodology reveals respiratory symptoms were a result of misuse in the majority of cases, as referenced by both reports of using bleach “undiluted” and/or mixing bleach with other cleaners resulting in accidental inhalation of vapors.²

1. Folletti, I.; Zock, J.-P.; Moscato, G.; Siracusa, A. J. *Asthma* **2014**, *51* (1), 18–28.

2. Medina-Ramon, M., Zock, J. P., Kogevinas, M., Sunyer, J., Torralba, Y., Borrell, A., Burgos, F., Anto, J. M., 2005. *Occup Environ Med.* *62*, 598-606.

Common Bleach Concerns

#4 Bleach causes Asthma

- There **are** many scientific studies that have been published that demonstrates how the use of sodium hypochlorite can reduce the allergens that trigger asthmatic symptoms.¹⁻³

Application	Results	Reference
Bleach used multiple times per week	<ul style="list-style-type: none">• Reduced sensitization to cat allergens• Reduced sensitization to dust mite matter	Zock et al, 2004 ³

1. Chen, P., Eggleston, P.A. 2001. Clin Exp Allergy 31:1086-1093
2. Matsui, E., Kagey-Sobotka, A., Chichester, K., Eggleston, P.A. 2003. J Allergy Clinical Immunology. 111:396-401.
3. Zock, J. P., Plana, E., Anto, J., Benke, G., Blanc, P., Carosso, A., Dahlman-Hoglund, A., Heinrich, J., Jarvis, D., Kromhout, H., 2009. J Allergy Clinical Immunology. 124: 731-738

Common Bleach Myths

#5 Bleach causes Cancer

Bleach does not cause Cancer

- ❑ Not classified as a human carcinogen (four studies)
 - 0.1 – 0.2% in drinking water of mice and rats for two years
 - 1-10% applied to skin of mice
- ❑ From The International Agency for Research on Cancer (IARC) - hypochlorite salts and chlorinated drinking water can not be classified as carcinogens to animals or humans.
- ❑ Not a mutagen
- ❑ No evidence of teratogenic or reproductive effects
- ❑ Approved by the US EPA for use as a preservative on raw foods, as a food additive for washing and peeling of fruits and vegetables; also by the FDA (21 CFR 173.315, 40 CFR 180.940)

Common Bleach Concerns

#6 Bleach damages Surfaces and Equipment

Bleach is safe for use on a variety of hard, nonporous surfaces, including stainless steel, plastics, glazed ceramics, glass, porcelain and other materials.

Surface damage can be attributed to:

- ❑ The oxidizing action of hypochlorite, salt residue and high pH
- ❑ With repeated or prolonged exposure, this may cause:
 - Damage to protein-based materials (leather, wool) and some polymers
 - Discoloration/corrosion of some metals
 - Harm to some painted surfaces
- ❑ Without rinsing, a visible salt residue may be left behind

These effects can be managed by

- Following label instructions.
- Rinsing/ wiping surfaces to prevent salt build up and damage.
- Using RTU formulated bleach products that contain anticorrosion agents.

Common Bleach Concerns:

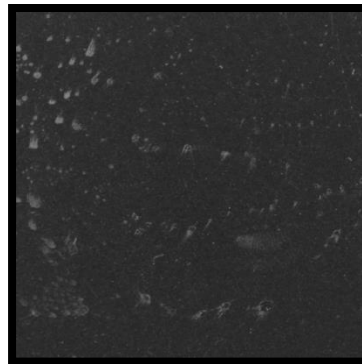
#6 Bleach damages Surfaces and Equipment

Managing Residue

- ❑ Cleaning and disinfectant products have the potential to cause residue if there are dissolved ingredients in the formula
 - This includes most commercially available healthcare cleaner/disinfectant products.
- ❑ Avoiding and managing residue is the best way to prevent surface damage



Bleach residue



Quat-Alcohol
residue



AHP residue

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

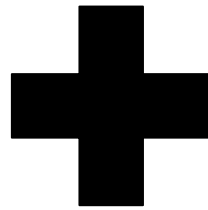
- Select the right product for the right job
- Always use bleach products as directed
- Review product labels and safety data sheets (SDSs) prior to product use
- Evaluate study methodology as well as results from science-based resources (Beware of misinformation)

Part 4

Bleach usage to prevent
pathogen transmission

Environmental Cleaning and Disinfection Strategies

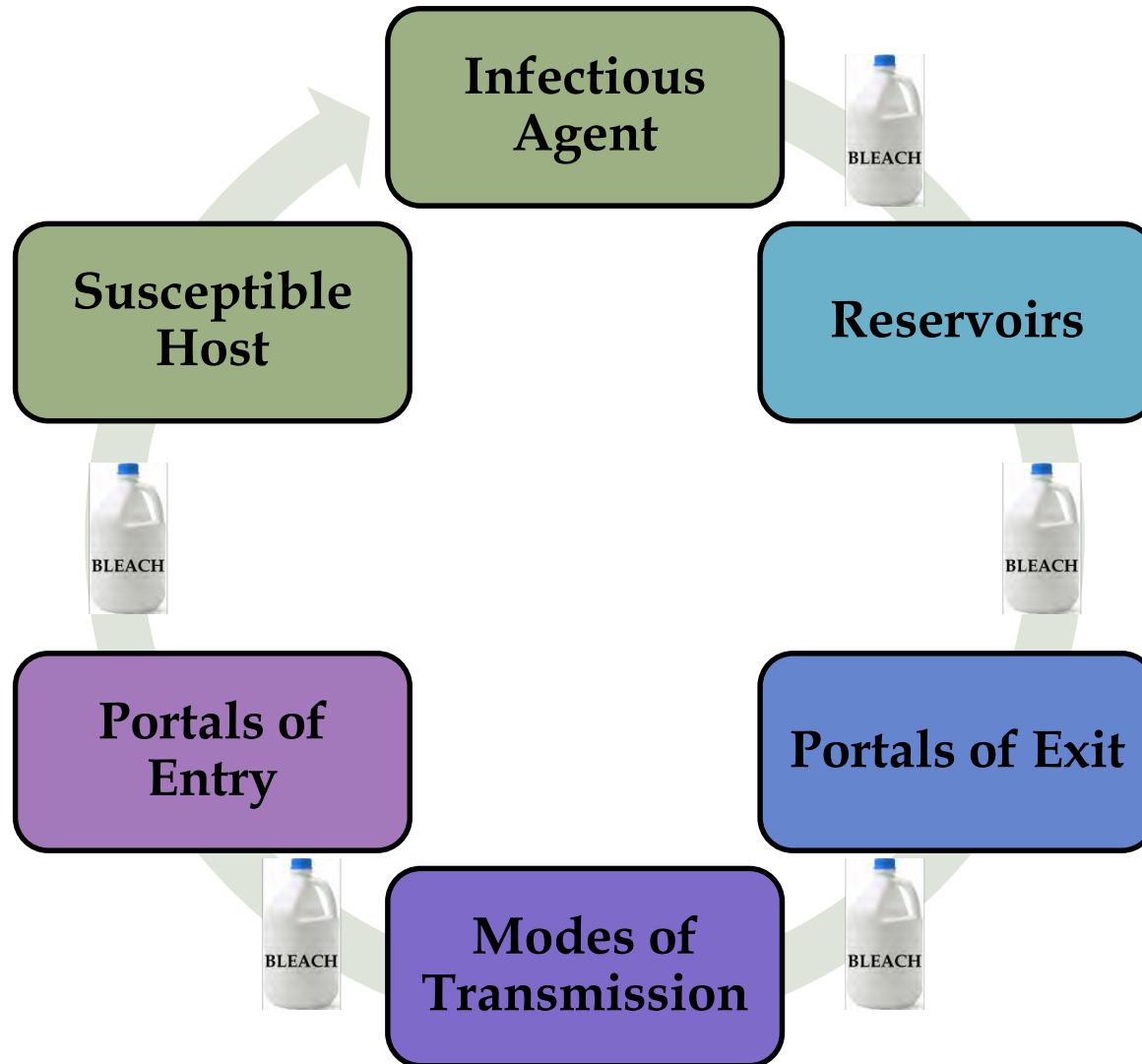
Product



Practice



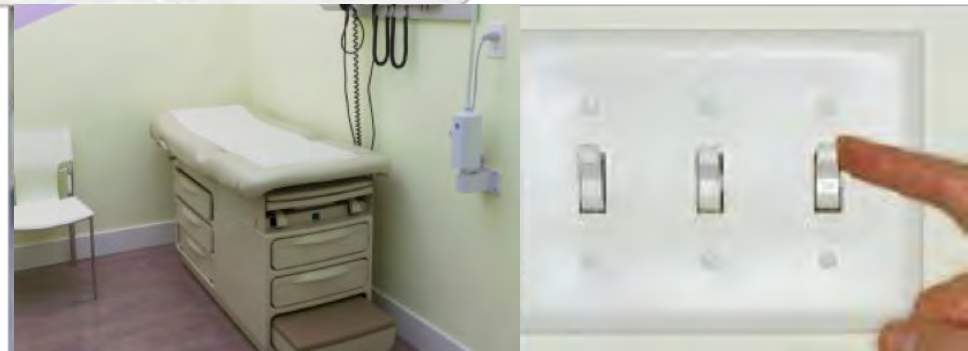
Using bleach to break the chain of transmission



Focus on Environmental Surfaces

- ❑ Surface contamination plays a key role in transmission of pathogens
- ❑ Almost 80% of infectious diseases are transmitted via touch¹
 - Direct: Healthcare worker hands to patient
 - Indirect: Healthcare worker hands to surface to patient

DIRECT OR
INDIRECT



1. Tierno, P. The Secret Life of Germs. New York, NY, USA: Atria Books, 2001.

Pathogen transfer in healthcare settings

Pathogens can survive on surfaces for months¹

C. difficile spores can transfer from CDI patient skin to HCW hands and environmental surfaces.²

Microorganism	Surface Viability
<i>Clostridium difficile</i>	Several months
methicillin resistant <i>Staphylococcus aureus</i> (MRSA)	Days to weeks
carbapenem-resistant <i>Klebsiella pneumoniae</i> (CRKP)	Days to months
vancomycin - resistant <i>Enterococci</i> (VRE)	Days to weeks



1. Kramer, A.; Schwebke, I.; Kampf, G. *BMC Infect. Dis.* **2006**, *6*, 130.
2. Bobulsky, G. S.; et al. *Clin. Infect. Dis.* **2008**, *46* (3), 447-450.

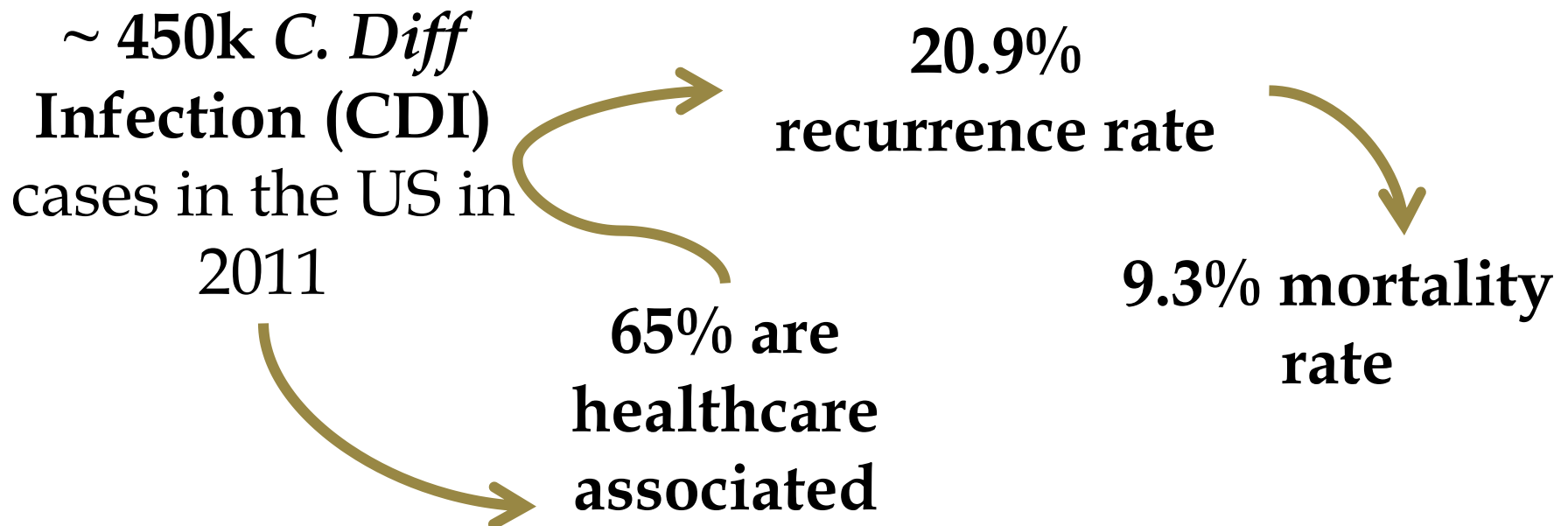
C. diff Spotlight: Most common HAI-causing pathogen



Clostridium difficile

Clostridium difficile (*C. diff*) is a bacteria found in the intestines that can cause diarrhea and serious illness.

The bacteria is found in feces and can spread via contact with contaminated surfaces.



C. diff Spotlight (Continued)

Did you know.....



Airborne *C. difficile* spores can be recovered in up to 25 cm (~10 inches) above the toilet seat after flushing a contaminated toilet.

Best, E. L.; Sandoe, J. A. T.; Wilcox, M. H. J. *Hosp. Infect.* **2012**, 80 (1), 1-5.



Up to 1 in 4 healthcare workers' hands are contaminated with *C. difficile* spores after caring for CDI patients.

Landelle, C.; et al. *Infect. Control Hosp. Epidemiol.* **2014**, 35 (1), 10-15.



Patients admitted to rooms previously housing CDI patients were 2X more likely to acquire CDI.

Shaughnessy, M. K.; et al. *Infect. Control Hosp. Epidemiol.* **2011**, 32 (3), 201-206.

Clinical evidence supporting use of bleach in acute care hospitals

Demonstrating operational benefits

Switching from cloth and bucket method to RTU bleach wipes for cleaning and disinfection was associated with **30% increase in cleaning compliance and time-related cost-savings of \$38 per employee per day.**¹

Reducing environmental contamination

After implementing a 3-stage intervention strategy including bleach-based disinfectants for CDI patient rooms, there was an **89% decrease in the prevalence of *C. diff*** on environmental surfaces.²

Reducing infection burden

Implementation of a bleach-based terminal cleaning program was associated with an **48% reduction in the prevalence density of patients with *C. difficile* infection.**³

References

1. Wiemken, T. L.; et al. *Am. J. Infect. Control* **2014**, 42 (3), 329–330.
2. Sitzlar, B.; et al. *Infect. Control Hosp. Epidemiol.* **2013**, 34 (5), 459–465.
3. Hacek, D. M.; et al. *Am. J. Infect. Control* **2010**, 38 (5), 350–353.

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*.

Questions



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Infection Control Resources

- ❑ Public Health Agency of Canada
- ❑ Provincial Infectious Diseases Advisory Committee (PIDAC) Routine Practices and Additional Precautions In All Health Care Settings, 3rd edition
- ❑ Centers for Disease Control and Prevention (CDC) HAI Resources
- ❑ World Health Organization (WHO) Infection Prevention and Control in Healthcare Resources

Bleach Resources

- ❑ [Facts About Bleach](#)
- ❑ [The Secret Life of Bleach Video](#)