Cleaning up Confusion about Bleach
Chemistry, Efficacy and Practical Applications in Healthcare Settings

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Disclosures

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- 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 complications\(^1\)
- 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 HAI\(^5\)
- Canadian attributable mortality rate 30 days after date of positive culture per 100 HA-CDI cases = 5.3

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>cases/1000 patient admissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. difficile</td>
<td>5.35/1000 (PHAC 2011)</td>
</tr>
<tr>
<td>MRSA</td>
<td>9.49/1000 (PHAC 2009)</td>
</tr>
<tr>
<td>VRE</td>
<td>0.51/1000 (PHAC 2011)</td>
</tr>
</tbody>
</table>

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

YOU CAN’T CONTROL WHAT COMES THROUGH THESE DOORS

OR CAN YOU?
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.

here...

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

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

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

<table>
<thead>
<tr>
<th>Laundry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanitizing &amp; disinfecting sinks, counters, floors in homes and institutional kitchens/restaurants</td>
</tr>
<tr>
<td>Removing mold &amp; mildew from floors, showers</td>
</tr>
<tr>
<td>Toilet bowl cleaners - cleaning and disinfecting</td>
</tr>
<tr>
<td>Drain cleaners</td>
</tr>
<tr>
<td>Disinfection of water in swimming pools, water treatment plants and natural wells</td>
</tr>
<tr>
<td>Textile &amp; paper whitening</td>
</tr>
</tbody>
</table>

### Healthcare Applications

<table>
<thead>
<tr>
<th>Laundry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning &amp; disinfecting environmental surfaces</td>
</tr>
<tr>
<td>Cleaning and disinfecting medical equipment</td>
</tr>
<tr>
<td>Cleaning and irrigating wounds</td>
</tr>
<tr>
<td>Endodontics (root canal irrigant)</td>
</tr>
</tbody>
</table>
# Sodium Hypochlorite Chemistry

<table>
<thead>
<tr>
<th>Common Names</th>
<th>Bleach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“Chlorine” Bleach</td>
</tr>
<tr>
<td></td>
<td>“Javex”</td>
</tr>
<tr>
<td></td>
<td>“Clorox”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Molecular Formula</th>
<th>NaOCl or NaClO</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Molecular Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>[structure image]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acid Base Equilibrium (weak acid, pKa ~ 7.4)</th>
<th>Sodium Hypochlorite ⇌ Hypochlorous Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOCl= hypochlorous acid</td>
<td>NaOCl + H⁺ ⇌ HOCl + Na⁺</td>
</tr>
<tr>
<td></td>
<td>HOCl + OH⁻ ⇌ H₂O + OCl⁻</td>
</tr>
</tbody>
</table>
Sodium Hypochlorite Chemistry

- Sodium hypochlorite is typically produced using a 2-step process:
  
  1. **Electrolysis:**
     
     \[ 2 \text{NaCl} + 2 \text{H}_2\text{O} \rightarrow \text{Cl}_2 + \text{H}_2 + 2 \text{NaOH} \]

  2. **Chlorine conversion:**
     
     \[ \text{Cl}_2 + 2 \text{NaOH} \rightarrow \text{NaOCl} + \text{NaCl} + \text{H}_2\text{O} \]

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

**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.

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

  \[
  \text{NaOCl} + \text{H}^+ \rightleftharpoons \text{HOCl} + \text{Na}^+ \\
  \text{HOCl} + \text{OH}^- \rightleftharpoons \text{H}_2\text{O} + \text{OCl}^- 
  \]

- Microbes do not develop resistance to sodium hypochlorite due to the non-specific destruction of proteins and other cellular components.
Hypochlorites react with proteins, lipids, carbohydrates, DNA, RNA... virtually all biological molecules.... And oxidize them!
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.
Sodium hypochlorite has broad spectrum antimicrobial activity against a wide range of microorganisms.

<table>
<thead>
<tr>
<th>Organism Class</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spores</td>
<td><em>C. difficile</em> spores</td>
</tr>
<tr>
<td>Mycobacteria</td>
<td>TB</td>
</tr>
<tr>
<td>Non-enveloped viruses</td>
<td>Norovirus</td>
</tr>
<tr>
<td>Fungi</td>
<td><em>Candida albicans</em></td>
</tr>
<tr>
<td>Vegetative Bacteria</td>
<td><em>Staph</em> (MRSA)</td>
</tr>
<tr>
<td>Enveloped viruses</td>
<td>Influenza A Virus</td>
</tr>
</tbody>
</table>

Increasing Resistance to Disinfectants
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.

<table>
<thead>
<tr>
<th>Sensitization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over time, the immune system identifies the allergen as an invader and develops antibodies called Immunoglobulin E (IgE).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Re-exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Allergy Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
</tr>
</tbody>
</table>
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.*

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

*Data generated internally by Clorox scientists
Part 3

Cleaning up Confusion about “Bleach” (NaOCl)
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.
Although referred to as “Chlorine Bleach” there is no free elemental chlorine ($\text{Cl}_2$) in bleach.

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

$$\text{Cl}_2 + 2 \text{NaOH} \rightarrow \text{NaOCl} + \text{NaCl} + \text{H}_2$$

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.”

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.
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
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.
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

<table>
<thead>
<tr>
<th>Application</th>
<th>Author conclusions²</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular use of bleach for cleaning</td>
<td>“cleaners who used bleach almost daily had a significant increase in risk of developing asthma.”</td>
<td>Medina-Ramon et al, 2005²</td>
</tr>
</tbody>
</table>

- 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

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.\textsuperscript{1-3}

<table>
<thead>
<tr>
<th>Application</th>
<th>Results</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleach used multiple times per week</td>
<td>• Reduced sensitization to cat allergens</td>
<td>Zock et al, 2004\textsuperscript{3}</td>
</tr>
<tr>
<td></td>
<td>• Reduced sensitization to dust mite matter</td>
<td></td>
</tr>
</tbody>
</table>

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)
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.
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
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

Infectious Agent

Susceptible Host

Reservoirs

Portals of Entry

Modes of Transmission

Portals of Exit
Surface contamination plays a key role in transmission of pathogens

Almost 80% of infectious diseases are transmitted via touch

- Direct: Healthcare worker hands to patient
- Indirect: Healthcare worker hands to surface to patient

Pathogens can survive on surfaces for months\textsuperscript{1}.

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Surface Viability</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Clostridium difficile</em></td>
<td>Several months</td>
</tr>
<tr>
<td>Methicillin resistant <em>Staphylococcus aureus</em> (MRSA)</td>
<td>Days to weeks</td>
</tr>
<tr>
<td>Carbapenem-resistant <em>Klebsiella pneumoniae</em> (CRKP)</td>
<td>Days to months</td>
</tr>
<tr>
<td>Vancomycin-resistant <em>Enterococci</em> (VRE)</td>
<td>Days to weeks</td>
</tr>
</tbody>
</table>

*C. difficile* spores can transfer from CDI patient skin to HCW hands and environmental surfaces.\textsuperscript{2}

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.

~ 450k C. Diff Infection (CDI) cases in the US in 2011

- 65% are healthcare associated
- 20.9% recurrence rate
- 9.3% mortality rate

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


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


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

## Clinical evidence supporting use of bleach in acute care hospitals

<table>
<thead>
<tr>
<th>Demonstrating operational benefits</th>
<th>Reducing environmental contamination</th>
<th>Reducing infection burden</th>
</tr>
</thead>
<tbody>
<tr>
<td>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</td>
<td>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</td>
<td>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</td>
</tr>
</tbody>
</table>

### References

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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Clorox Professional Products Company

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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**