Disinfection 101

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DISCLOSURE

- Jim is employed by Diversey. His expenses to present (salary) are paid by this company. Diversey has had no input into this presentation from a commercial interest.

OBJECTIVES

- Discuss cleaning, disinfecting and sterilization
  - How they work
  - Common issues
  - Common disinfectant chemistries

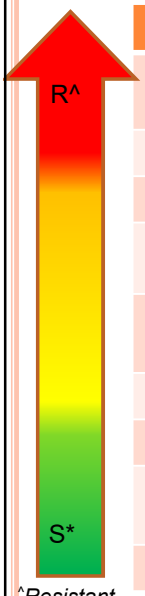
KEY TERMINOLOGY

- Antimicrobial
  - capable of killing microorganisms. Does not specify the type or quantity of pathogens killed
- "cidal" versus "static"
  - "cidal" means that the product is capable of killing the organism – i.e. bactericidal kills bacteria
  - "static" means it prevents the growth – i.e. fungistatic prevents the growth of fungi
- Bactericidal
  - capable of killing bacteria.

Key Terminology

- Fungicidal – capable of killing fungi
- Germicidal – older term meaning the same as antimicrobial
- Virucidal – capable of killing viruses
  - PHAC
    - Virucide – capable of killing a virus
    - Broad-spectrum virucide - representative hard to kill non-enveloped virus
      - poliovirus type 1, human adenovirus type 5, or bovine or canine parvovirus

Effect of Disinfectants on Microorganisms



^Resistant
* Sensitive

Organism	Type	Examples
Bacterial Spores	Spore	*Bacillus anthracis, Clostridioides difficile*
Mycobacteria	Bacteria	*M. tuberculosis*
Small non-enveloped virus	Virus	Poliovirus, Norovirus, Rhinovirus, Hep A
Fungal spores	Fungus	Aspergillus, Penicillium, Trichophyton
Gram negative bacteria	Bacteria	*E. coli*, Klebsiella including CRE, Pseudomonas, Acinetobacter
Fungi (Vegetative)	Fungus	Candida
Large Virus (non-enveloped)	Virus	Adenovirus, Rotavirus
Gram positive bacteria	Bacteria	Staphylococcus including MRSA Enterococcus including VRE
Virus (enveloped)	Virus	HIV, HBV, HCV, Influenza, RSV, SARS

Adapted from Rutala et al. ICHE 2014;35(7):862

Definitions

Cleaning

- Removing all foreign material (i.e. dirt, body fluids, lubricants) from objects by using water and detergents or soaps, and washing or scrubbing the object
- Cleaning must be done before any disinfection or sterilization process so that foreign material will not keep the process from working

Log

- Multiples of 10 (if base 10) equaling a % decrease
  - 2 log = 99%, 3 log = 99.9%, 6 log = 99.9999%

Definitions

Decontamination

- Make an object or surface safe to handle (see "Cleaning")

Sanitizing

- A process that reduces the number of microorganisms on a surface
  - 3 log on non-food contact surfaces or soft surfaces (USA)
  - 5 log on food contact surfaces

Disinfection

- A process that eliminates many or all microorganisms except spores, and is done with liquid chemicals or by pasteurizing objects
- High, Intermediate, Low Levels

DEFINITIONS

Pasteurization (aka Thermal Disinfection)

- A high-level disinfection process using hot water at a temperature of 71°C (160°F) for a minimum exposure time of at least 30 minutes
- Generally used for respiratory equipment and tubing
- For food processing, much shorter contact time

DEFINITIONS

Sterilization

- A process that completely eliminates or kills all microorganisms using:
  - sterilizers that provide steam under pressure
  - dry heat
  - ethylene oxide (ETO) and other gases
  - liquid chemicals

Definitions

Antiseptic

- Agent used to reduce microbial load on skin or tissue
  - Alcohol-based hand rubs
  - Chlorhexidine tincture
  - Povidone Iodine

Definitions

Vegetative Bacteria

- The growing form of bacteria
  - Includes both Gram positive and Gram negative bacteria
  - Includes both aerobic and anaerobic bacteria

Spore

- The resistant form of certain bacteria
  - Survives harsh environmental conditions
  - Tolerant to many disinfectant technologies

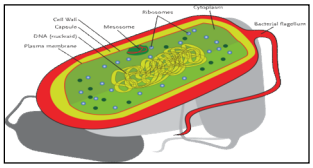
How do disinfectants kill?

Bacteria and Fungi

- Breaks cell wall, leaking out intracellular contents (oxidizers)
- Interrupts cell processes (quats/phenolics)
- Dehydrates the cell (alcohol)

Viruses

- Chemically reacts with organism and breaks it down
- Think of it as chemically burning the organism, which causes it to die



How do disinfectants kill?

- Antibiotics work through a specific "lock and key" process.
- Disinfectants are less elegant.
  - They are the sledgehammer to the watermelon
- Thus, there's minimal risk that bacteria will become immune to disinfectants the way they have antibiotics.

Resistant Organisms

- Antibiotic resistance does NOT confer disinfectant resistance!
  - *E. coli* is *E. coli* whether it can produce a beta lactamase or a carbapenemase

Antibiotics

Antibiotic Resistance – Lock and Key

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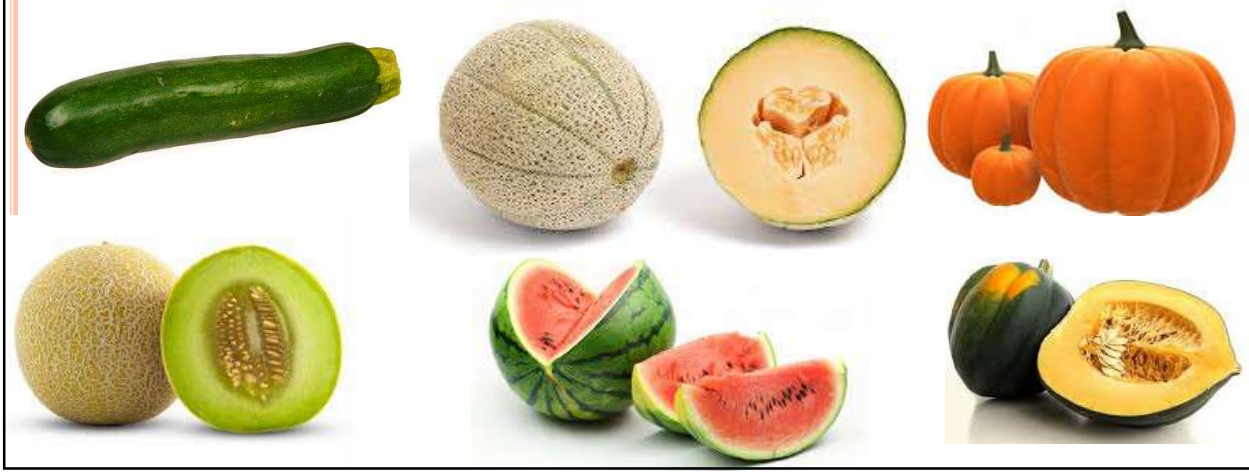
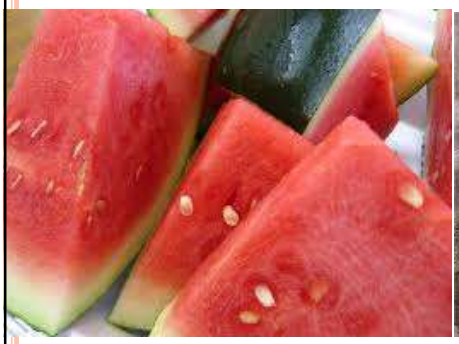
Analogy for Disinfectants



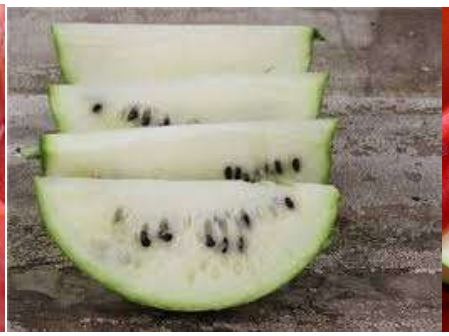
The Family Tree

- **Family** • Cucurbitaceae
- **Genus** • Last Name
- **Species** • First Name

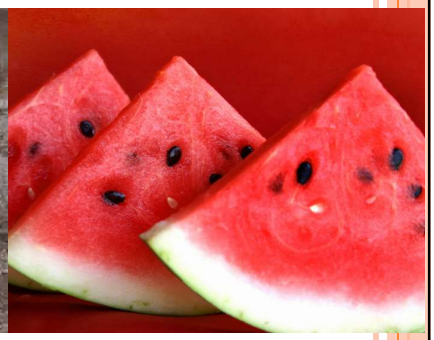
Genetic Mutations



Watermelon coli



Watermelon ESBL



Watermelon CRE

Underlying Principles

Clean before disinfecting!

Underlying Principles

Equipment can be reused if it is labeled for reuse, cleaned, and reprocessed according to manufacturer's instructions

Single patient use should remain single patient use

SPAULDING CLASSIFICATION

Divides healthcare equipment into 3 categories based on objects the potential risk of infection involved in their use

- Critical
- Semi-critical
- Non-critical

PIDAC 2013

SPAULDING CLASSIFICATION

Critical – enter normally sterile tissue or the vascular system

Spaulding Classification

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Semi-Critical – contact with mucous membranes or non-intact skin

Spaulding Classification

Critical – enter normally sterile tissue or the vascular system

Semi-Critical – contact with mucous membranes or non-intact skin

Non-Critical – contact with intact skin

- Bedpans
- Commode
- Urinals

Spaulding Classification

Critical
- Must be sterilized and used sterile

Semi-Critical
- Must receive at least High level Disinfection

Non-Critical
- Must receive at least Low level Disinfection

Disinfection Levels

High Level
- Kills all microorganisms, with the exception of high numbers of bacterial spores

Adapted from Rutala et al. ICHE 2014;35(7):862

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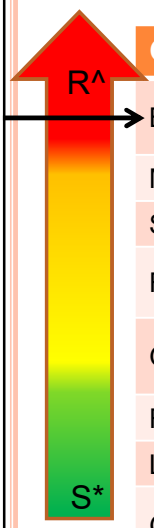

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High

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Intermediate Level

- Kills *M. tuberculosis*, vegetative bacteria, most viruses and fungi, but not spores

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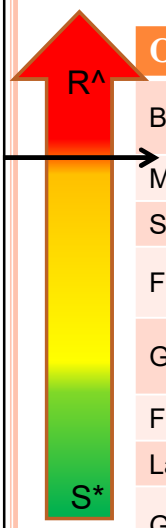

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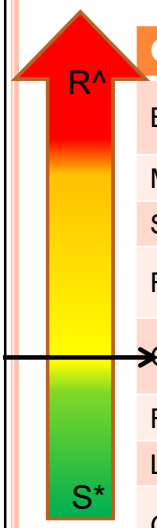
Disinfection

High
- Kills all microorganisms, with the exception of high numbers of bacterial spores

Intermediate
- Kills *M. tuberculosis*, vegetative bacteria, most viruses and fungi, but not spores

Low Level
- Kills vegetative bacteria, enveloped viruses
  - Hospital Disinfectant
  - Pseudo and Staph aureus

Effect of Disinfectants on Microorganisms



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Methodology

Sterilization is preferred over High Level Disinfection if tolerated or available

- Margin of safety
  - Always allow for a wide margin of safety

STERILIZATION

Steam Autoclaves

- Must be moisture resistant
- Wrapping and structure of equipment must allow penetration of steam
- 121-132°C for 20-30 minutes at 15 PSI (100kPa)

STERILIZATION

- Foot care equipment
  - "…must be sterile…"
    - Sterile at point of use?
    - Sterilized and used clean?
  - Steam, chemical sterilants
    - Storage issues, rinse with sterile water
  - IPAC-Canada – used sterile

Ideal Disinfectant (Rutala 2014)

1. **Broad spectrum** – kills pathogens of concern relevant to setting
2. **Fast acting** – short kill and contact times listed on label
3. **Remains wet** – keep surfaces wet for entire contact time in single application
4. **Unaffected by environmental factors** – not affected by organic matter, compatible with cleaners
5. **Non-toxic and non-irritating to the user** – should have lowest possible safety risk to user
6. **Compatible with surfaces** – should be proven compatible with common Healthcare surfaces and equipment

Ideal Disinfectant

7. **Persistence** – should have a residual effect on surfaces
8. **Easy to use** – available in multiple forms to align with highest convenience for users
9. **Acceptable odor** – should have an acceptable odor for residents and staff
10. **Economical** – should not be cost prohibitive for facility
11. **Soluble in water** – so will not cause issues when it contacts water
12. **Stable** - in concentrate and end-use dilution
13. **Cleaner** - good cleaning ability
14. **Nonflammable** – should have a flash point over 150°F

Key Considerations for Selecting the Optimal Disinfectant for Your Facility

Rutala 2014 (2)

Scoring

Consideration	Score (1-10)
Kill Claims	
Kill Times and Wet Contact Time	
Safety	
Ease of Use	
Other Factors	

Kill Claims

Does the product kill the most prevalent healthcare pathogens, including those that:

- Cause most HAIs*?
- Cause most outbreaks?
- Are of concern in your facility?

TABLE 3. Most Prevalent Pathogens Causing Healthcare-Associated Infections (HAIs)

Recommended organism (% of HAIs caused)	Why organisms are relevant
Staphylococcus aureus (15.6%)	Most prevalent overall contributors to HAIs (NHSN/CDC)[11]
Escherichia coli (11.5%)	
Coagulase-negative *Staphylococcus* (11.4%)	
Klebsiella (8.0%)	
Pseudomonas aeruginosa (7.5%)	
Enterococcus faecalis (6.8%)	
Candida albicans (5.3%)	
Enterobacter species (4.7%)	
Other *Candida* species (4.2%)	
Enterococcus faecium (4.1%)	
Enterococcus species (3.0%)	
Proteus species (2.5%)	
Serratia species (2.1%)	
Acinetobacter baumanni (1.8%)	

~27%

~53%

79% (without Yeasts)

Rutala 2014

Table 3. Reported Causative Pathogens, According to Type of Infection.*

Magill 2014

Pathogen	All Health Care–Associated Infections (N=504)†		Pneumonia (N=110)	Surgical-Site Infections (N=110)	GI Infections (N=86)	UTIs (N=65)	Bloodstream Infections (N=50)
	no. (%)	*rank*			*number (percent)*		
Clostridium difficile	61 (12.1)	1	0	0	61 (70.9)	0	0
Staphylococcus aureus	54 (10.7)	2	18 (16.4)	17 (15.5)	1 (1.2)	2 (3.1)	7 (14.0)
Klebsiella pneumoniae or *K. oxytoca*	50 (9.9)	3	13 (11.8)	15 (13.6)	1 (1.2)	15 (23.1)	4 (8.0)
Escherichia coli	47 (9.3)	4	3 (2.7)	14 (12.7)	1 (1.2)	18 (27.7)	5 (10.0)
Enterococcus species‡	44 (8.7)	5	2 (1.8)	16 (14.5)	5 (5.8)	11 (16.9)	6 (12.0)
Pseudomonas aeruginosa	36 (7.1)	6	14 (12.7)	7 (6.4)	1 (1.2)	7 (10.8)	2 (4.0)
Candida species§	32 (6.3)	7	4 (3.6)	3 (2.7)	3 (3.5)	3 (4.6)	11 (22.0)
Streptococcus species¶	25 (5.0)	8	7 (6.4)	8 (7.3)	2 (2.3)	2 (3.1)	2 (4.0)
Coagulase-negative staphylococcus species	24 (4.8)	9	0	7 (6.4)	0	1 (1.5)	9 (18.0)
Enterobacter species	16 (3.2)	10	3 (2.7)	5 (4.5)	0	2 (3.1)	2 (4.0)
Acinetobacter baumannii	8 (1.6)	11, tie	4 (3.6)	2 (1.8)	0	0	0
Proteus mirabilis	8 (1.6)	11, tie	1 (0.9)	5 (4.5)	0	1 (1.5)	0
Yeast, unspecified	8 (1.6)	11, tie	3 (2.7)	0	1 (1.2)	4 (6.2)	0
Stenotrophomonas maltophilia	8 (1.6)	11, tie	6 (5.5)	0	0	2 (3.1)	0
Citrobacter species	6 (1.2)	15, tie	2 (1.8)	1 (0.9)	0	1 (1.5)	0
Serratia species	6 (1.2)	15, tie	2 (1.8)	0	0	2 (3.1)	0
Bacteroides species	6 (1.2)	15, tie	0	5 (4.5)	1 (1.2)	0	0
Haemophilus species	6 (1.2)	15, tie	2 (1.8)	2 (1.8)	0	0	0
Viruses‖	3 (0.6)	19, tie	1 (0.9)	0	0	0	0
Peptostreptococcus species	3 (0.6)	19, tie	0	2 (1.8)	0	0	1 (2.0)

Pathogen	All Health Care–Associated Infections (N=504)†		Pneumonia (N=110)	Surgical-Site Infections (N=110)	GI Infections (N=86)	UTIs (N=65)	Bloodstream Infections (N=50)
	no. (%)	*rank*			*number (percent)*		
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Staphylococcus aureus	54 (10.7)	2	18 (16.4)	17 (15.5)	1 (1.2)	2 (3.1)	7 (14.0)
Klebsiella pneumoniae or *K. oxytoca*	50 (9.9)	3	13 (11.8)	15 (13.6)	1 (1.2)	15 (23.1)	4 (8.0)
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Enterococcus species‡	44 (8.7)	5	2 (1.8)	16 (14.5)	5 (5.8)	11 (16.9)	6 (12.0)
Pseudomonas aeruginosa	36 (7.1)	6	14 (12.7)	7 (6.4)	1 (1.2)	7 (10.8)	2 (4.0)
Candida species§	32 (6.3)	7	4 (3.6)	3 (2.7)	3 (3.5)	3 (4.6)	11 (22.0)
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Enterobacter species	16 (3.2)	10	3 (2.7)	5 (4.5)	0	2 (3.1)	2 (4.0)

65%

Pathogen	All Infections (N=427)	Pneumonia (N=110)†	Gastrointestinal Infection (N=91)‡	Surgical-Site Infection (N=69)§	Bloodstream Infection (N=52)¶	Urinary Tract Infection (N=39)‖	Other Infection (N=66)**
	number of infections (percent)						
C. difficile	66 (15)	0	66 (73)	0	0	0	0
Staphylococcus aureus	48 (11)	13 (12)	2 (2)	12 (17)	12 (23)	0	9 (14)
Escherichia coli	44 (10)	2 (2)	1 (1)	13 (19)	4 (8)	18 (46)	6 (9)
Candida species	26 (6)	7 (6)	3 (3)	1 (1)	7 (13)	3 (8)	5 (8)
Enterococcus species	23 (5)	1 (1)	2 (2)	8 (12)	6 (12)	4 (10)	2 (3)
Enterobacter species††	22 (5)	3 (3)	1 (1)	10 (14)	0	3 (8)	5 (8)
Pseudomonas aeruginosa	22 (5)	8 (7)	2 (2)	3 (4)	0	5 (13)	4 (6)
Klebsiella pneumoniae or *K. oxytoca*	21 (5)	6 (5)	1 (1)	3 (4)	3 (6)	7 (18)	1 (2)
Streptococcus species‡‡	21 (5)	4 (4)	1 (1)	9 (13)	6 (12)	0	1 (2)
Coagulase-negative staphylococcus	16 (4)	1 (1)	2 (2)	6 (9)	6 (12)	0	1 (2)

Magill 2018

Most common causes of outbreaks and ward closures by causative pathogen, which are relatively hard to kill

Clostridioides difficile spores
Norovirus / (Rhinovirus)
Aspergillus
Rotavirus
Adenovirus

Kill Times and Wet-Contact Time

- How quickly does the product kill the prevalent healthcare pathogens?
- Does the product keep surfaces visibly wet for the kill times listed on its label?

Safety

- Does the product have an acceptable toxicity rating?
- Does the product have an acceptable flammability rating?
- Is a minimal level of Personal Protective Equipment (PPE) required?
- Is the product compatible with the common surfaces in your facility?

Ease of Use

- Is the product odor considered acceptable?
- Does the product have an acceptable shelf-life?
- Does the product come in convenient forms
  - liquids
  - sprays
  - refills
  - multiple wipe sizes
  - etc.

Ease of Use

- Does the product work in the presence of organic matter?
- Is the product water soluble?
- Does the product clean and disinfect in a single step?
- Are the directions for use simple and clear?

Other Factors

- Does the supplier offer comprehensive training and ongoing education, both in-person and virtual?
- Does the supplier offer 24-7 customer support?
- Is the overall cost of the product acceptable (considering product capabilities, costs of infections that may be prevented and costs per compliant use)?
- Can the product help standardize disinfectants used in your facility?

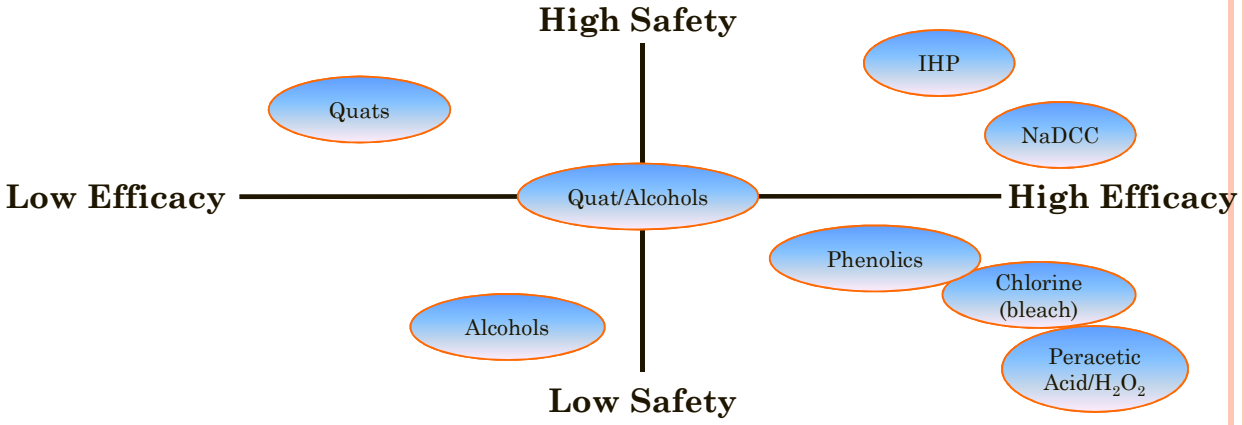
Total Score?

Consideration	Score (1-10)
Kill Claims	
Kill Times and Wet Contact Time	
Safety	
Ease of Use	
Other Factors	

Last Thought

- Evidence from peer-reviewed journals that product works?
  - Efficacy in lab is great…but real life can be different!

Disinfectant Chemistries – Balancing Tradeoffs



- **Trade-offs** between customer needs and product performance. There is no one disinfectant that does everything well.

Chemistry Report Card

talkcleantome.blogspot.com

	Broad Spectrum of Efficacy	Realistic Contact Time	Superior Cleaning Efficacy	Safer to Use	Environmental Profile
Improved H_2O_2	A to B	A to B	A	A to B	A to B
QUATs	C	C	B	B-	C+
QUAT/Alcohol	A to B	A to B	C	C to D	B to C
Phenolics	B to C	C	B	D	C
Chlorine	A to C	A to C	D	B to D	C
Peracetic Acid	A to C	B to C	C to D	B to C	A to B

Store Brands

- Quat based
- Sanitize (99.9% of germs only - 3 $\log_{10}$) 30 sec
- Disinfect (99.999) – 4 minutes
- Cold and Flu viruses?

Effect of Disinfectants on Microorganisms

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R^

S*

^Resistant
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Adapted from Rutala et al. ICHE 2014;35(7):862

Chemistry time!

Sodium Hypochlorite Advantages

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

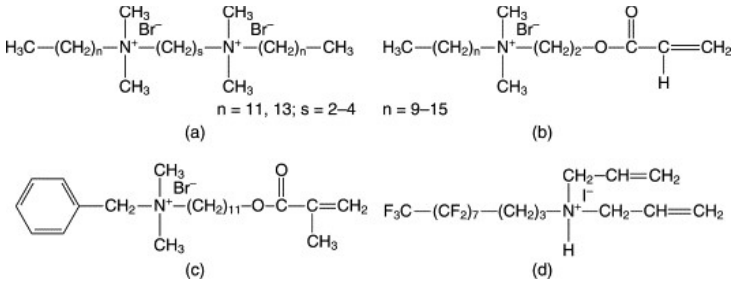
- Bactericidal, tuberculocidal, fungicidal, virucidal
- Sporicidal – in high conc.
- Fast acting
- Inexpensive (in dilutable form)
- Not flammable
- Unaffected by water hardness
- Reduces biofilms on surfaces
- Relatively stable (e.g., 50% reduction in chlorine concentration in 30 days)
- Used as the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

Sodium Hypochlorite 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

Quats

- Quaternary ammonium compounds
  - N-Alkyl (69% C_{12}, 32% C_{14}) dimethyl ethylbenzyl ammonium chlorides
  - N-Alkyl (60% C_{14}, 30% C_{16}, 5% C_{12}, 5% C_{18}) dimethyl benzyl ammonium chloride



QUATS ADVANTAGES

- Bactericidal, fungicidal, virucidal against enveloped viruses (e.g., HIV)
- Good cleaning agents
- EPA registered
- Surface compatible
- Non-staining
- Persistent antimicrobial activity when undisturbed
- Inexpensive (in dilutable form)
- Not flammable

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QUATS DISADVANTAGES

- Not sporicidal
- In general, not tuberculocidal and virucidal against non-enveloped viruses
- Longer Contact Time
- Residue left on surfaces
- High water hardness and cotton/gauze can make less microbicidal
- A few reports documented asthma as result of exposure to benzalkonium chloride
- Multiple outbreaks ascribed to contaminated benzalkonium chloride

QUATS/ALCOHOL-SOLVENT ADVANTAGES

- Bactericidal, fungicidal, virucidal
- EPA registered
- Surface compatible
- Non-staining
- Low Residue
- Faster than Quats

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QUATS/ALCOHOL-SOLVENT DISADVANTAGES

- Not sporicidal
- May not kill small non-enveloped viruses
- Flammable (check your fire compartment rating)
- Contact time hard to achieve with solvent flash off
- Can cause skin/eye irritation
- Generally require PPE (gloves and in some cases goggles)
- Odor can be an issue

Improved Hydrogen Peroxide Advantages

- Bactericidal, tuberculocidal, fungicidal, virucidal
- Fast efficacy
- Easy compliance with wet-contact times
- Safe for workers (lowest EPA toxicity category, IV)
- Benign for the environment
- Surface compatible
- Non-staining
- EPA registered
- Not flammable

Improved H.P. Disadvantages

- (Perceived as) More expensive than some other disinfecting actives
- Not sporicidal at low concentrations
  - Alfa et. al. found some products to have 2 – 3 log kill of *C. difficile* spores
  - Cadnum et. al. found ~2.6 log kill
  - Some materials incompatibility

Healthcare Environment

- Effective cleaning is more important than what is used
- Microfiber cloths
  - New issues coming to light
  - Possible to have quat binding
  - Cleans well, but does not wash well!
    - Check if done in-house
- Single dip methods
  - Only once into bucket with cloth
  - Wet cloth with squirt bottle
  - Pre-wetted wipes

Quat Binding

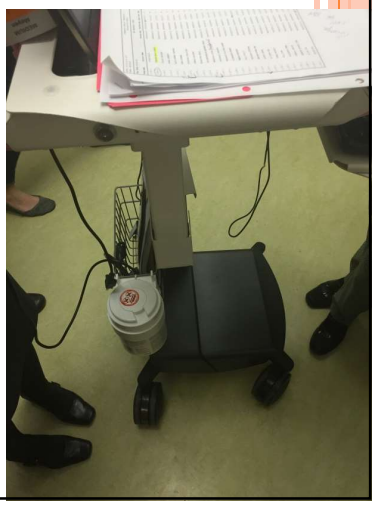
- Active ingredient (Quat) binds to cleaning cloth
  - Removed from solution
  - Wiping surface with wet cloth!
- All cotton cloths (towels, facecloths)
- Some microfiber cloths
- Check with quat test strip

Cleaning equipment

- Must be clean (PIDAC)
  - No bathtub ring in mop buckets
  - No topping up of bottles
  - If using refillable buckets with dry cloths – bucket must be cleaned after use before refilling with wipes and solution! (Kampf 2014)

Environmental Cleaning

- It can be difficult!
- Use pre-wetted wipes (Alfa 2015, Boyce 2017)
  - Attach to equipment
  - Within resident care area (point of care) if chemistry is safe
  - Odors and VOC's



How Often?

Targeted Moments of Environmental Disinfection (TMED):

1. Before placing food/drink on an over-bed table
2. Before/after any aseptic practice (care to wounds, lines, etc.)
3. After any procedure involving feces or respiratory secretions within a bed space
4. After patient/resident bathing (within a bed space)
5. After any object used on/by a patient/resident touches the floor

Gauthier 2020

Simply

- If, during care, you touched it or used it: disinfect it!

How Often?

- Public Restrooms?
- Outbreaks in community (Norovirus)
- Number of people triggers an EVS page?

Summary

- We need to keep an eye on our environment
- We need to clean effectively and regularly
- Effective cleaning is not near as expensive as an outbreak!

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