The Role of the Environment in the Transmission of Infection – How Can We Intervene?

PROFESSOR ELAINE CLOUTMAN-GREEN

HOSTED BY BARBARA CATT, IFIC

Summary

Are all organisms linked to similar risk profiles?

Are all built environments the same?

Determine what kind of options are open for:

Identifying the source	Addressing the problem	Continuous risk mitigation

What Is Meant By the Environment?

Air

- Mechanical/naturally ventilated environments

Water

- Water sources
  - Taps/Showers
  - Sterile water
  - Equipment

Surfaces

- Near patient
- Shared area

Risk Assessment

- Routes of transmission
- Patient loads
- Environmental persistence
- Infectious dose
- Colonised/infectious state
- Patient susceptibility
- Timing of infection (community vs hospital acquired)
- Endogenous vs exogenous
- Surveillance
  - Clinical (active vs symptom lead)
  - Environmental

Does the IPC Triumvirate Work?

Figure 1. Exposure to a *Clostridioides difficile* "contaminated" bed. Beds are considered contaminated (red) starting with the positive *C. difficile* test of an occupant (green occupant). The bed remains contaminated for 90 days and "resets" every time a new patient with *C. difficile* is identified in that bed. Subsequent occupants (blue and orange) are considered to have an associated hospital-onset *C. difficile* infection (HO-CDI) if they develop their infection ≥3 days after being admitted and while residing in the contaminated bed or within 7 days of leaving the contaminated bed (orange occupant with star).

C. difficile Outbreak

Witt LS, Howard-Anderson J, Prakash-Asrani R, Overton E, Jacob JT. The role of the hospital bed in hospital-onset Clostridioides difficile: A retrospective study with mediation analysis. *Infection Control & Hospital Epidemiology*. 2024;45(5):599-603

Not All Patients are the Same

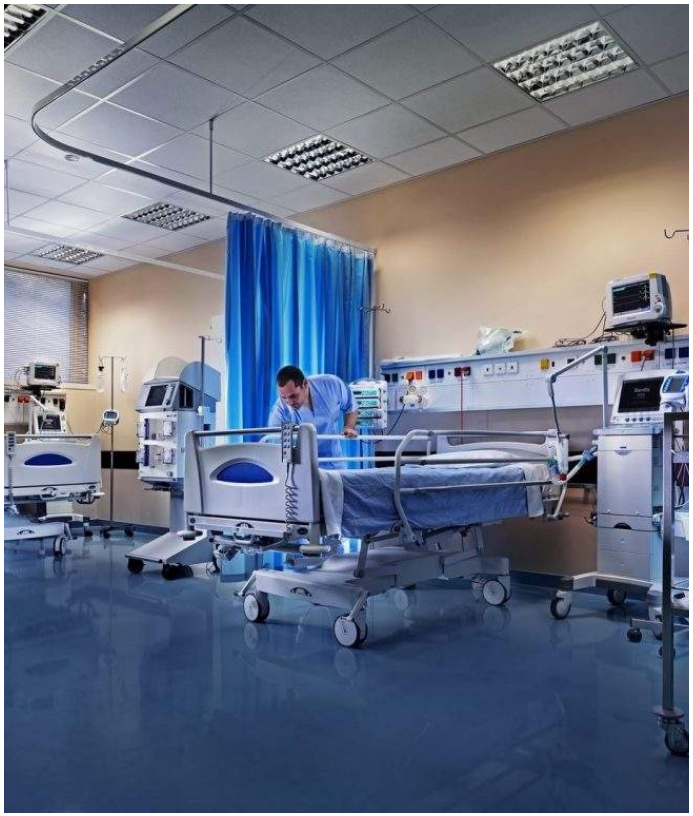
Table II
Range of survival by pathogen

	Pathogen	Range of survival in days (unless otherwise indicated)	Studies (references)
Gram positive	*Staphylococcus aureus*	<1 min to 318	[7–32]
	Clostridioides difficile	0.13–140	[33–36]
	Coagulase-negative *Staphylococcus*	<1 min to 28	[12,23,24,37]
	Micrococcus spp.	10–10	[12]
	Streptococcus mutans	0.13–0.2	[21]
	Bacillus spp.	1–28	[22,24]
	Enterococcus spp.	0.02–287	[10,12,14,15,19,22,24,39,43,45,47–49]
Gram negative	*Acinetobacter* spp.	0.04–90	[12,14,15,22,24,29,38–43]
	Burkholderia cepacia	0.13–8	[12,44]
	Citrobacter freundii	0.06–0.11	[45]
	Escherichia coli	<1 min to 56	[8,10,12–15,20–24,43,45,46]
	Klebsiella pneumoniae	0.57–600	[15,43,45,50,51]
	Proteus mirabilis	0.16–0.16	[43]
	Pseudomonas spp.	0.08–7	[8,10,12,15,18,19,22,24,29,43,44,47,52,53]
	Salmonella spp.	0.29–5	[12]
	Serratia spp.	0.29–20	[12,14,15,22,43]
	Stenotrophomonas maltophilia	0.29–1	[12]
	Haemophilus influenzae	1–1	[19]
Fungi	*Candida auris*	14–14	[54]
	Candida spp.	0.13–28	[20–22,36,54,55]
Virus	Animal virus	0.5–7	[56,57]
	Coronavirus	0.04–20	[58–60]
	Cytomegalovirus	<1 min to 0.01	[61]
	Human virus	<1 min to 12	[57,62–66]
	SARS-CoV	1–2	[67]

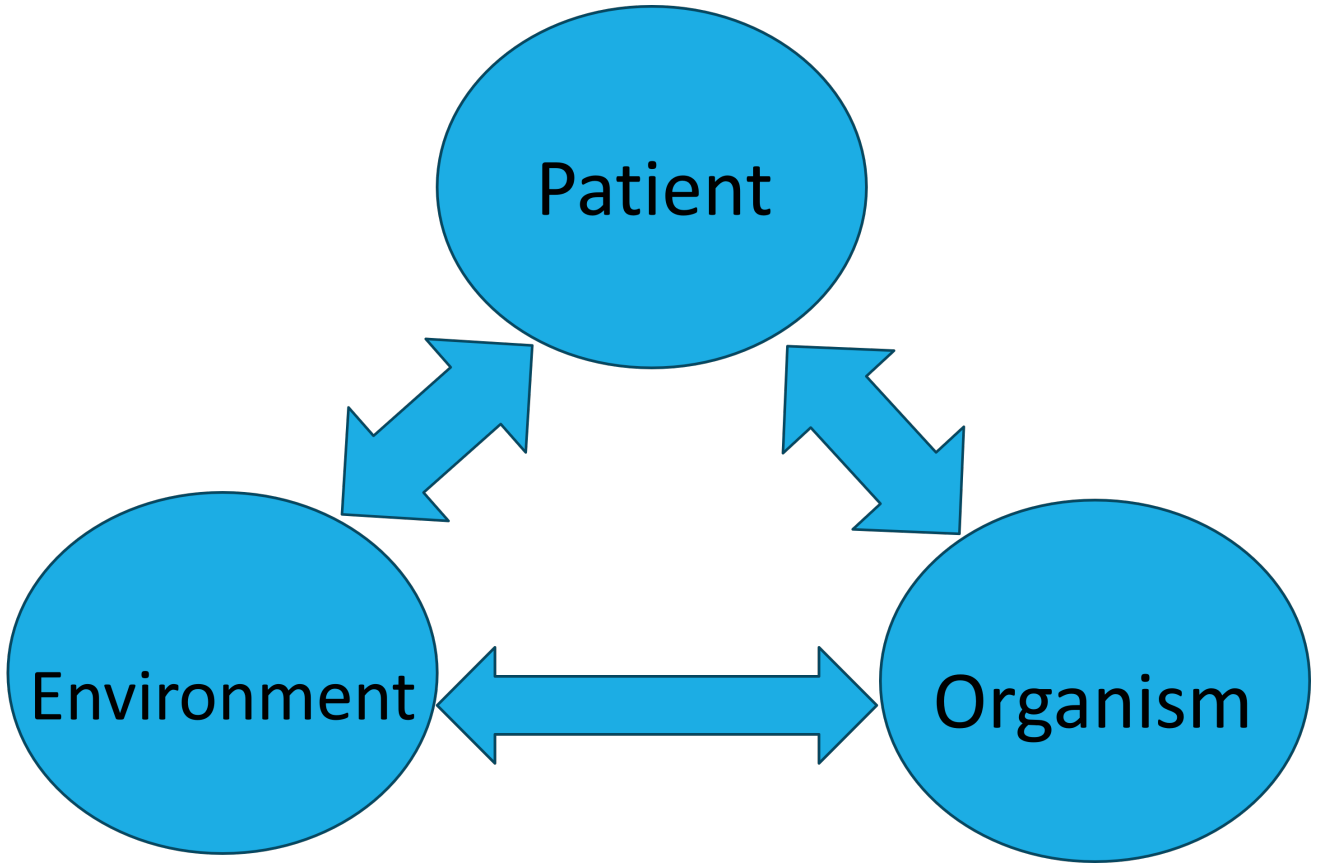
Human virus – hepatitis A virus, herpes simplex, human immunodeficiency virus, influenza, parainfluenza, respiratory syncytial virus. Animal virus – pseudorabies, bovine viral diarrhoea virus, feline calicivirus, canine parvovirus.

Not All Organisms Are Equal

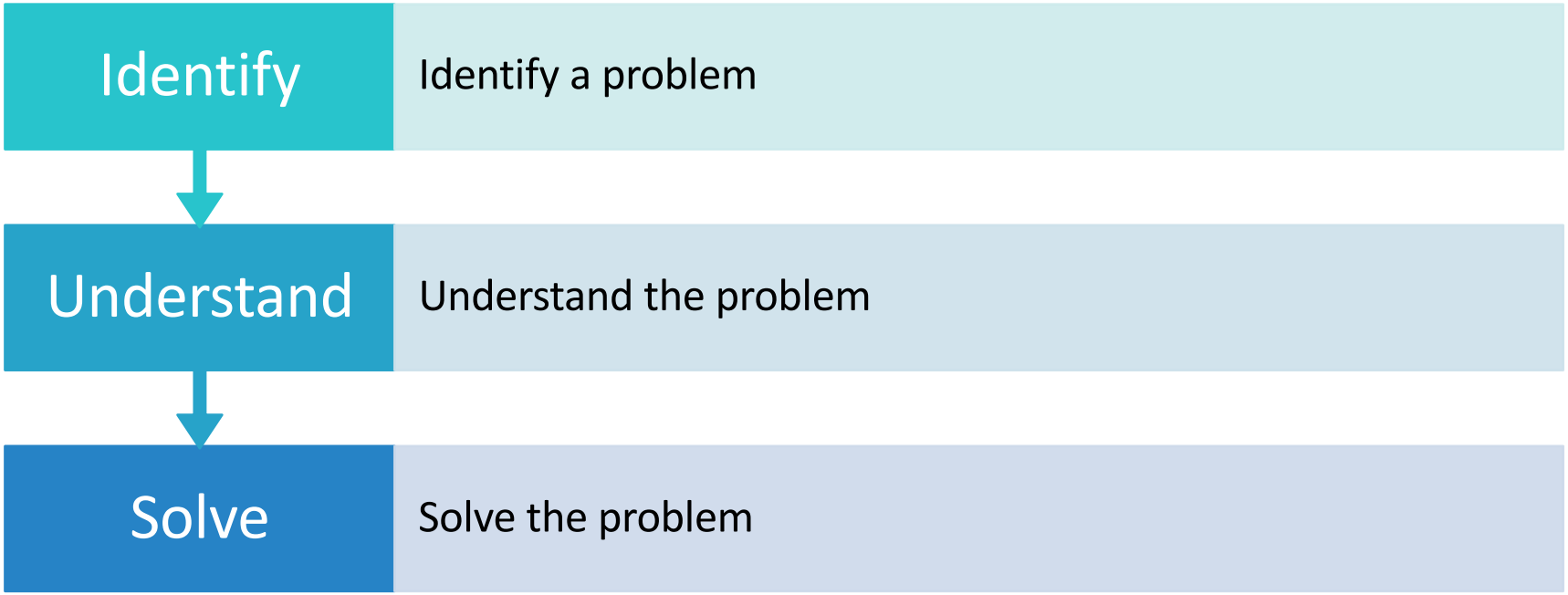
L. Porter, O. Sultan, B.G. Mitchell, A. Jenney, M. Kiernan, D.J. Brewster, P.L. Russo,
How long do nosocomial pathogens persist on inanimate surfaces? A scoping review,
Journal of Hospital Infection, Volume 147, 2024, 25-31,


Built Environments Vary


Patient
Environment
Organism

How Do We:


Identify
Identify a problem
Understand
Understand the problem
Solve
Solve the problem

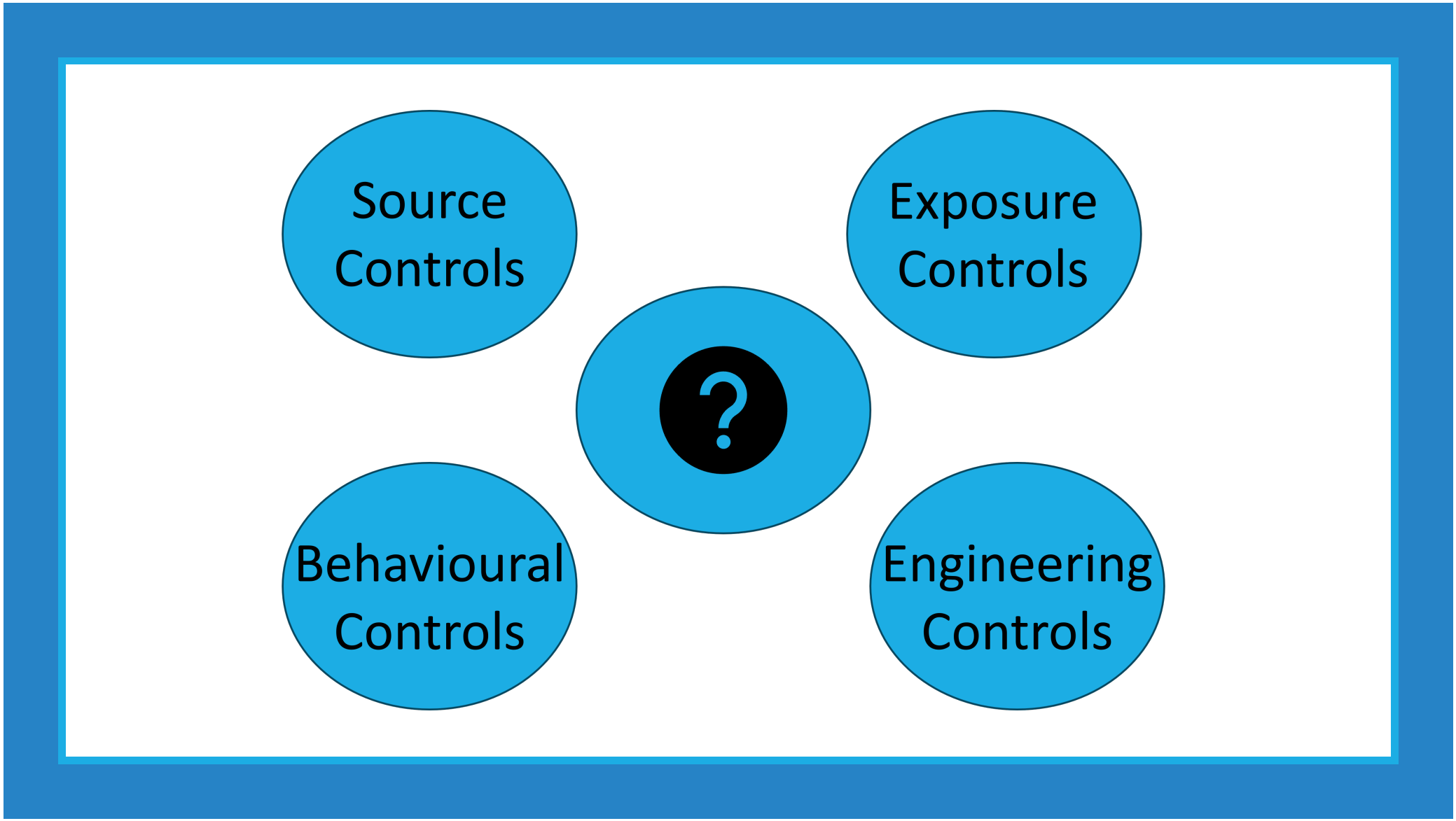
Context Matters

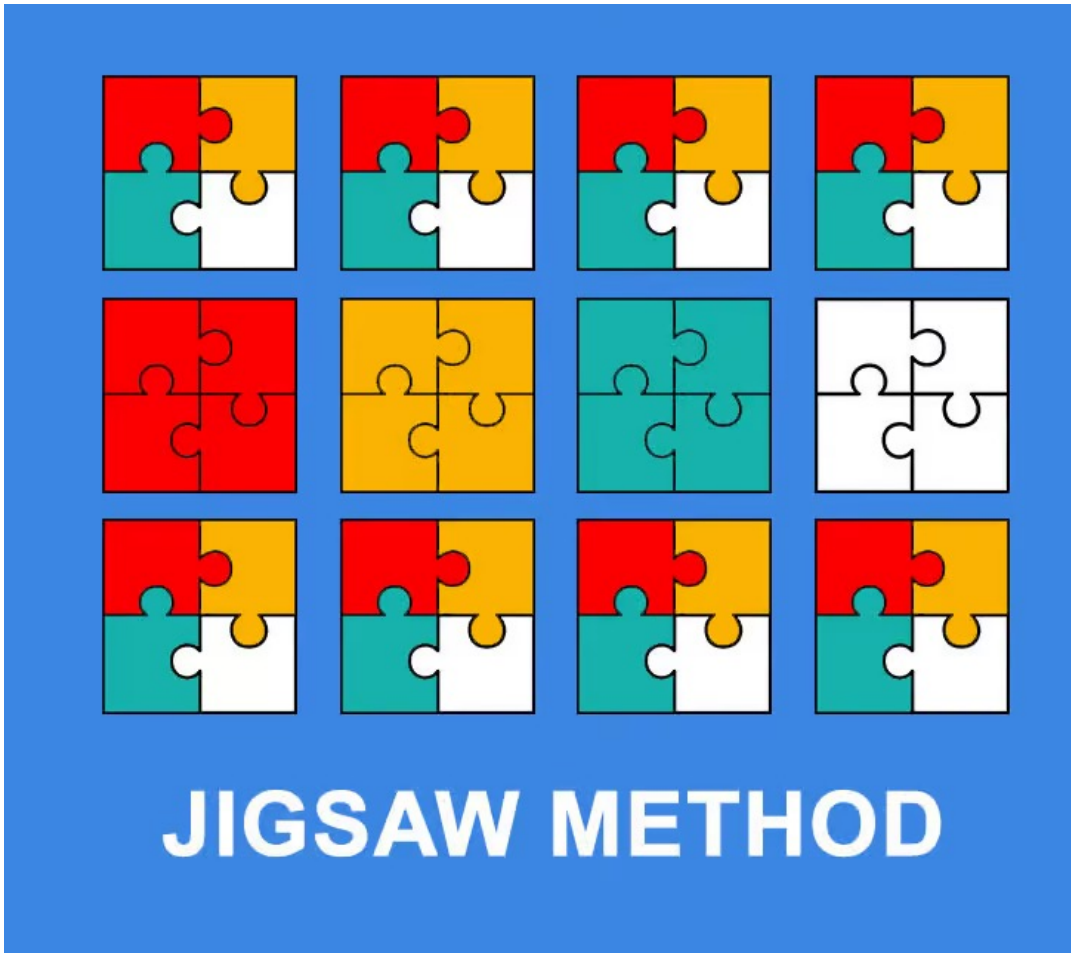
OUTBREAK VS ROUTINE

SHORT TERM VS LONG TERM CARE

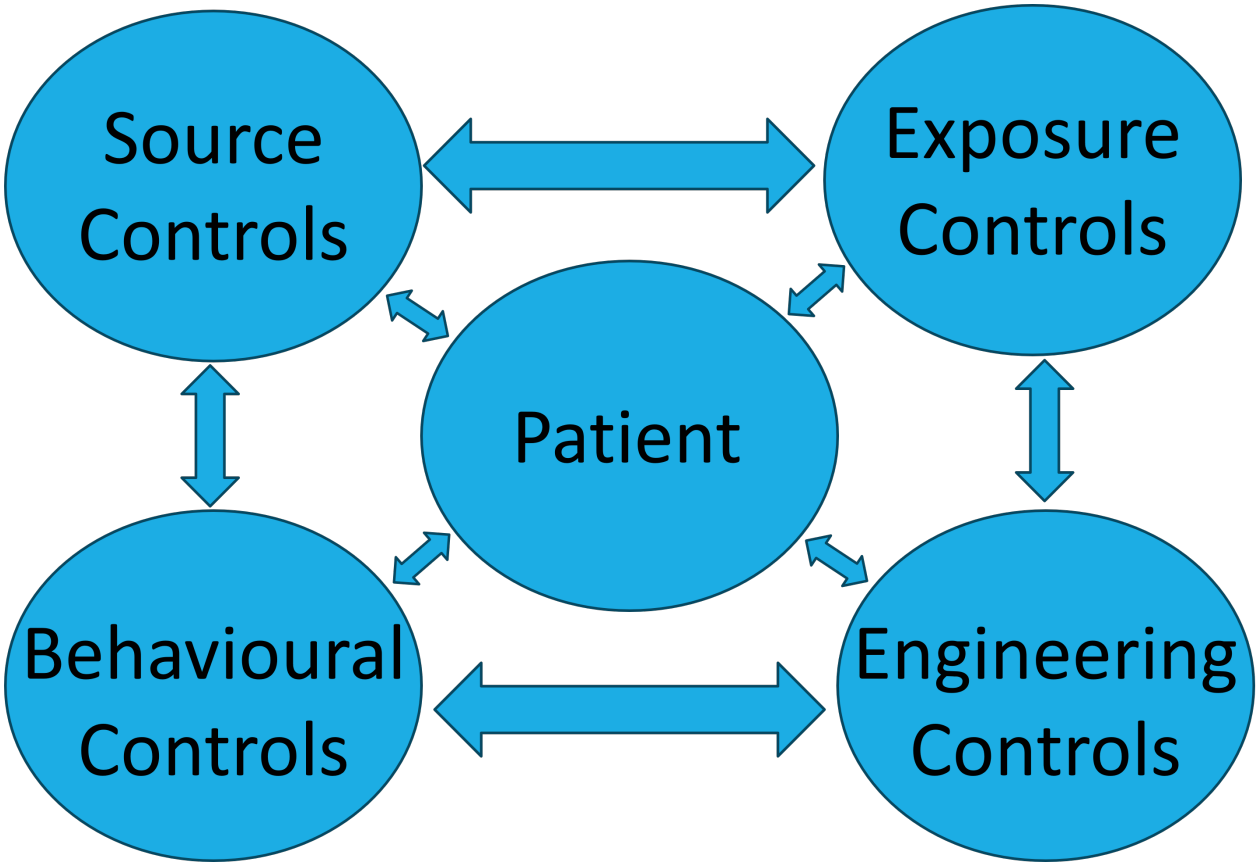
ACUTE VS COMMUNITY CARE

HIGH RISK VS LOW RISK SETTINGS


Source Controls
Exposure Controls
?
Behavioural Controls
Engineering Controls



Toolkit


Source Controls
Exposure Controls
Patient
Behavioural Controls
Engineering Controls

Source Controls

Source Control Toolkit

IDENTIFICATION OF SOURCE

UNDERSTANDING THE DYNAMIC NATURE OF THE ENVIRONMENT

DESIGNING YOUR SHORT-TERM SOURCE REMOVAL

CONSIDERATION OF LONG-TERM APPROACHES - REMOVAL OF HIGH-RISK SOURCES

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Journal of Hospital Infection

journal homepage: www.elsevier.com/locate/jhin

Review

How to carry out microbiological sampling of healthcare environment surfaces? A review of current evidence

S. Rawlinson [a], L. Ciric [a], E. Cloutman-Green [a,b,*]

[a] University College London, Chadwick Building, Department of Civil, Environmental and Geomatic Engineering, London, UK
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Infection prevention and control

SUMMARY

There is increasing evidence that the hospital surface environment contributes to the spread of pathogens. However, evidence on how best to sample these surfaces is inconsistent and there is no guidance or legislation in place on how to do this. The aim of this review was to assess current literature on surface sampling methodologies, including the devices used, processing methods, and the environmental and biological factors that might influence results. Studies published prior to March 2019 were selected using relevant keywords from ScienceDirect, Web of Science, and PubMed. Abstracts were reviewed and all data-based studies in peer-reviewed journals in the English language were included. Microbiological air and water sampling in the hospital environment were not included. Although the numbers of cells or virions recovered from hospital surface environments were generally low, the majority of surfaces sampled were microbiologically contaminated. Of the organisms detected, multidrug-resistant organisms and clinically significant pathogens were frequently isolated and could, therefore, present a risk to vulnerable patients. Great variation was found between methods and the available data were incomplete and incomparable. Available literature on sampling methods demonstrated deficits with potential improvements for future research. Many of the studies included in the review were laboratory-based and not undertaken in the real hospital environment where sampling recoveries could be affected by the many variables present in a clinical environment. It was therefore difficult to draw overall conclusions; however, some recommendations for the design of routine protocols for surface sampling of healthcare environments can be made.

Planning Ahead

Rawlinson S, Ciric L, Cloutman-Green E. How to carry out microbiological sampling of healthcare environment surfaces? A review of current evidence. J Hosp Infect. 2019 Jul 29

Interpretation Criteria

Colony Forming Units:

<2.5 CFU/cm^2

<5 CFU/cm^2

10 CFU/m^3

Pathogen detection: present/absent

Organism specific: *Pseudomonas aeruginosa/Legionella pneumophila*

Trend analysis

Custom

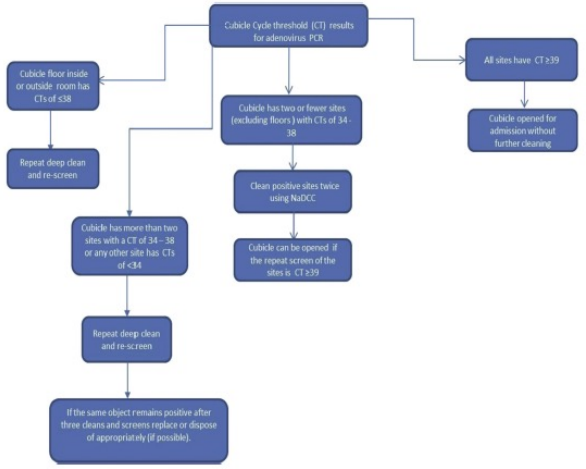
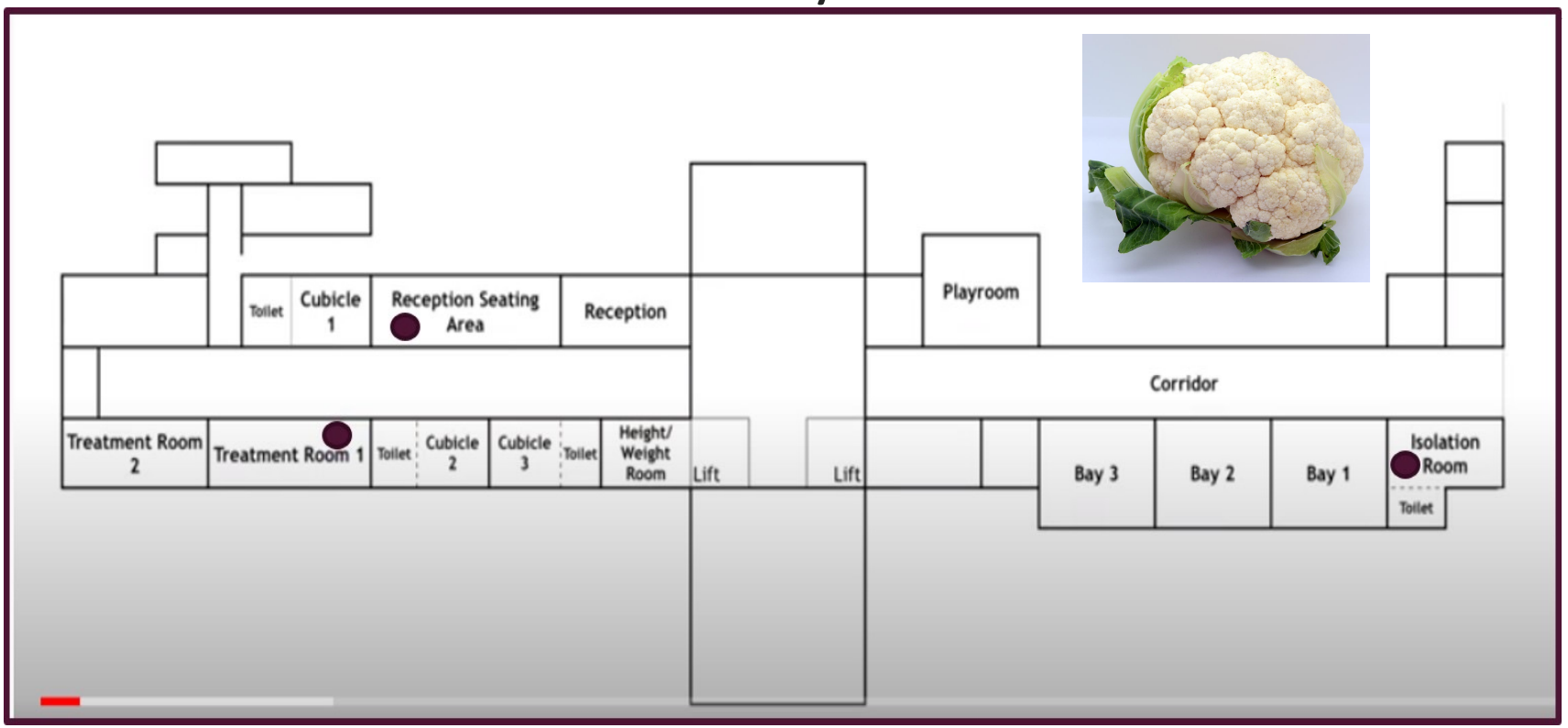
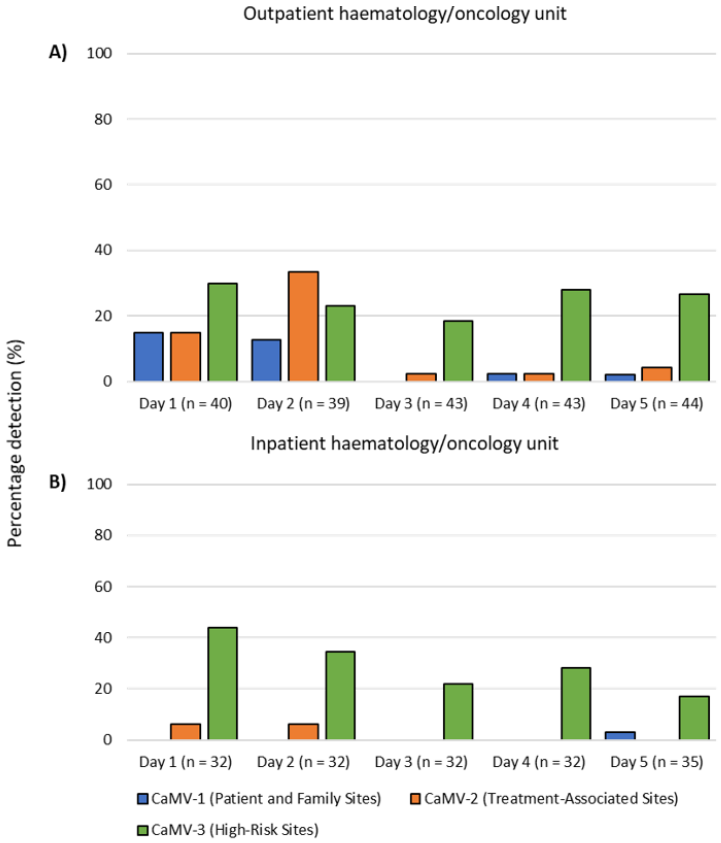


Fig 1. Routine monitoring algorithm for interpreting and using adenovirus polymerase chain reaction (PCR) results in relation to environmental screening. *CT*, cycle threshold; *NaDCC*, 1,000 ppm chlorine.

Cloutman-Green E, Canales M, Pankhurst L, et al. Development and implementation of a cleaning standard algorithm to monitor the efficiency of terminal cleaning in removing adenovirus within a pediatric hematopoietic stem cell transplantation unit. American journal of infection control. 2015 Sep 1;43(9):997-9.

A One Size Fits All May Not Work





The Environment is a Dynamic Space

DATA FROM SAM WATKIN – MANUSCRIPT IN PREPARATION

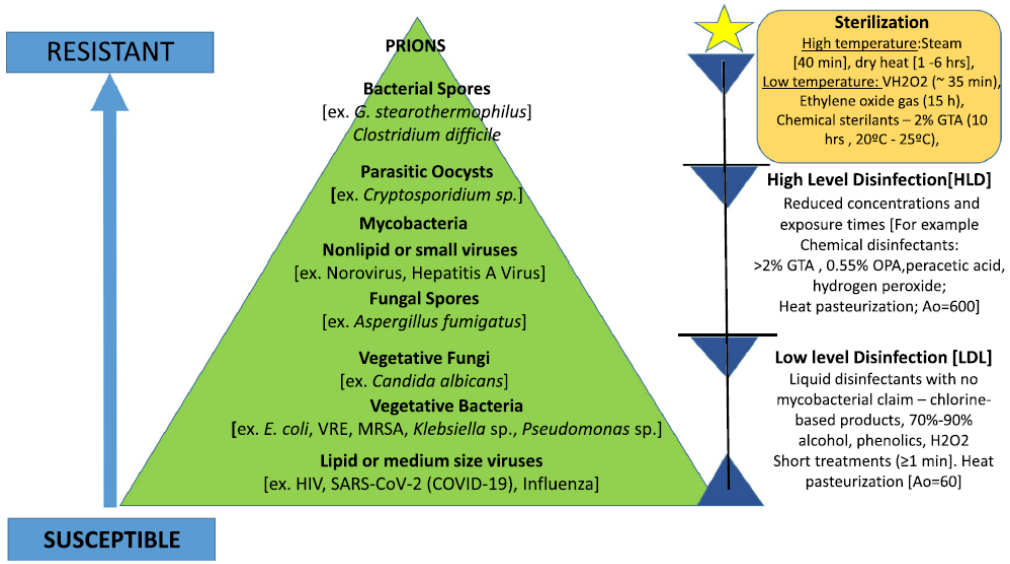


Fig. 1. Pyramid of increasing microbial resistance to disinfectants and sterilants [Noting, this is a guide as the actual levels of resistance depend on the type of disinfection/ sterilization process].

Pick the Right Agent for the Right Risk

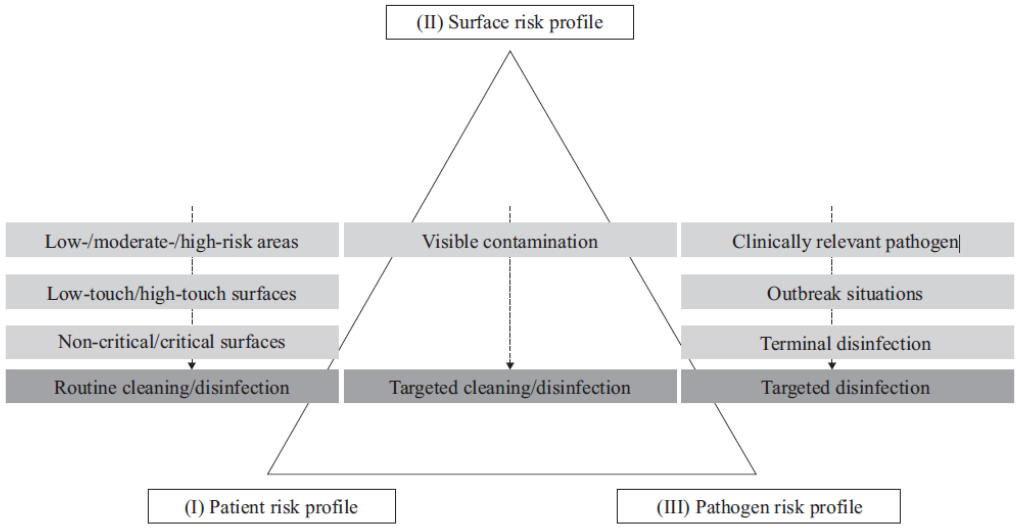
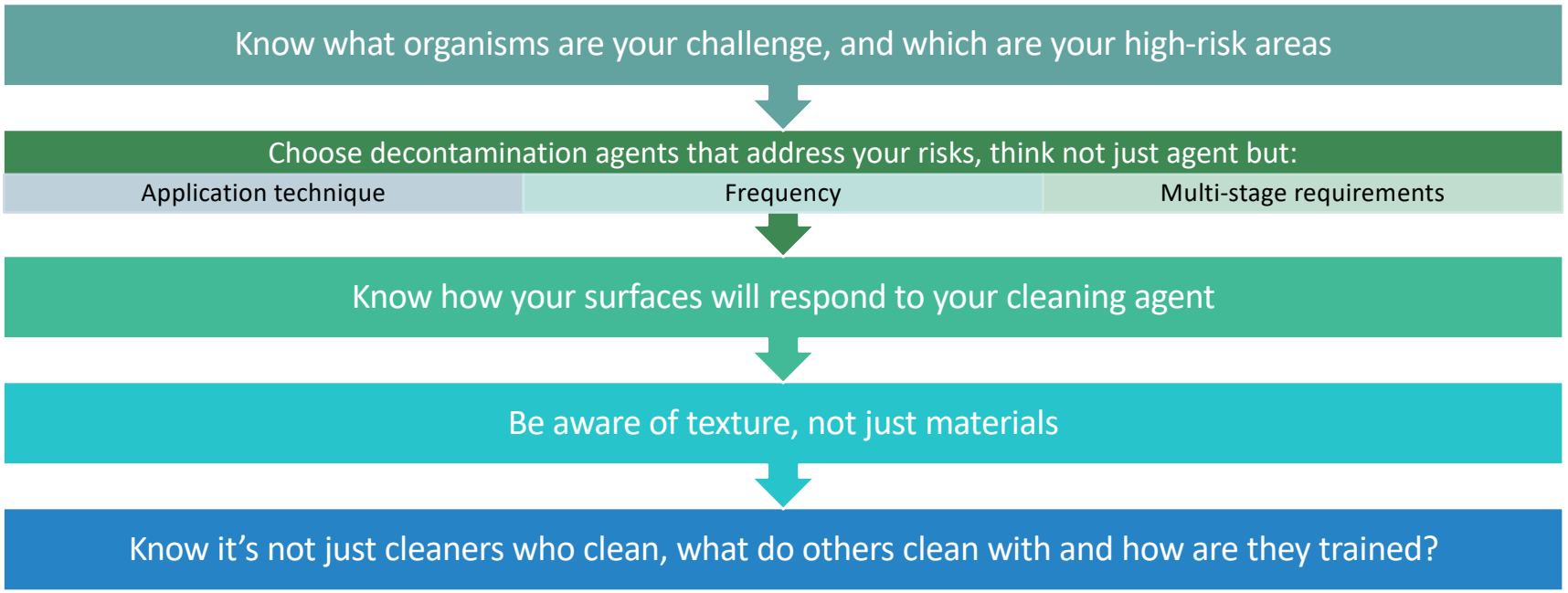


Figure 1. Comprehensive overview of the fundamental principles of a risk analysis.

Factors to Consider When Designing Your Cleaning Approach

Journal of Hospital Infection
113 (2021) 104 to 114

Considerations for Surface Decontamination



Exposure Controls

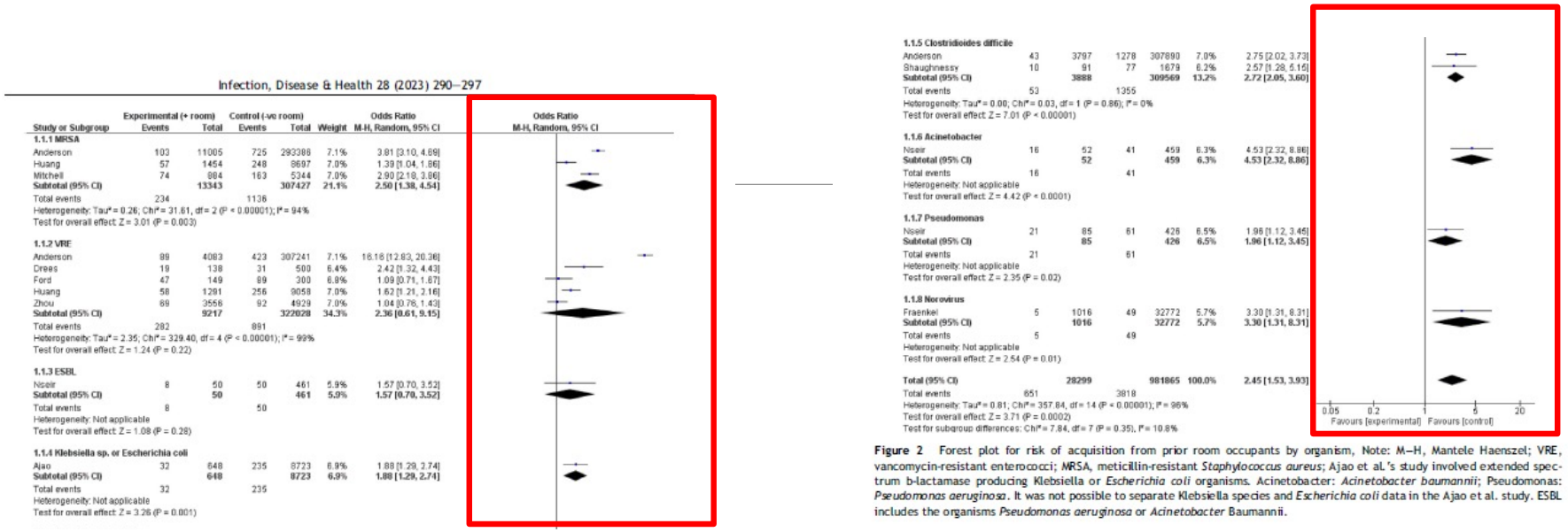


Figure 2 Forest plot for risk of acquisition from prior room occupants by organism, Note: M–H, Mantele Haenszel; VRE, vancomycin-resistant enterococci; MRSA, meticillin-resistant *Staphylococcus aureus*; Ajao et al.'s study involved extended spectrum b-lactamase producing Klebsiella or *Escherichia coli* organisms. Acinetobacter: *Acinetobacter baumannii*; Pseudomonas: *Pseudomonas aeruginosa*. It was not possible to separate Klebsiella species and *Escherichia coli* data in the Ajao et al. study. ESBL includes the organisms *Pseudomonas aeruginosa* or *Acinetobacter* Baumannii.

Prior Room Occupation Data

Brett G. Mitchell, Julee McDonagh, Stephanie J. Dancer, Sindi Ford, Jenny Sim, Bismi Thottiyil Sultanmuhammed Abdul Khadar, Philip L. Russo, Jean-Yves Maillard, Helen Rawson, Katrina Browne, Martin Kiernan, Risk of organism acquisition from prior room occupants: An updated systematic review, Infection, Disease & Health, Volume 28, Issue 4, 2023, 290-297

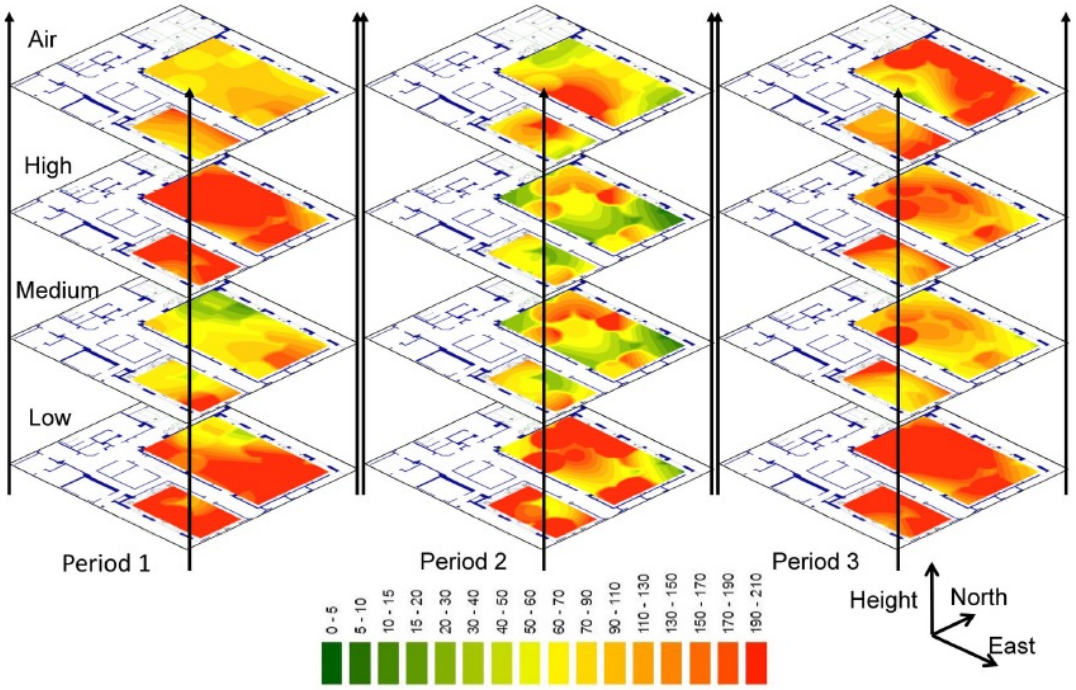


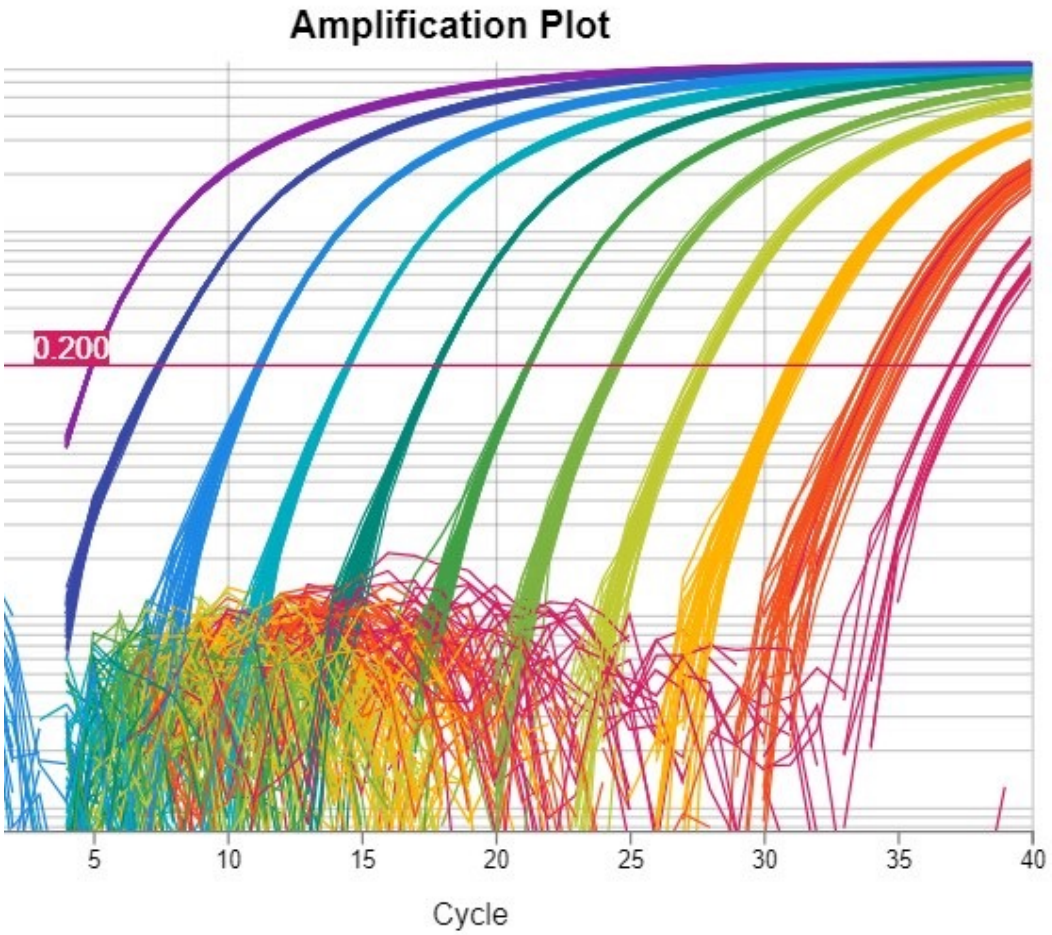
Figure 2. Estimation of the counts of micro-organisms. Results were adjusted on bedside, bed occupancy, height level (for surface analysis), Ward and location. Total Viable Count (TVC) estimations for the three cross-sectional surveys at the different height levels including air sampling are presented at each location. The coloured scale showed the values of TVC.

doi: 10.1371/journal.pone.0076249.g002

Placement Matters

Gaudart J, Cloutman-Green E, Guillas S, D'Arcy N, Hartley JC, Gant V, Klein N. Healthcare environments and spatial variability of healthcare associated infection risk: cross-sectional surveys. PLoS One. 2013 Sep 19;8(9):e76249


Notes:
All dimensions to be checked on site. Figured dimensions to be taken in preference to scaled dimensions.
Negative pressure
PPVL
SIR
Pelican Ward



Surface Loading Impacts Exposure and Removal Efficiency

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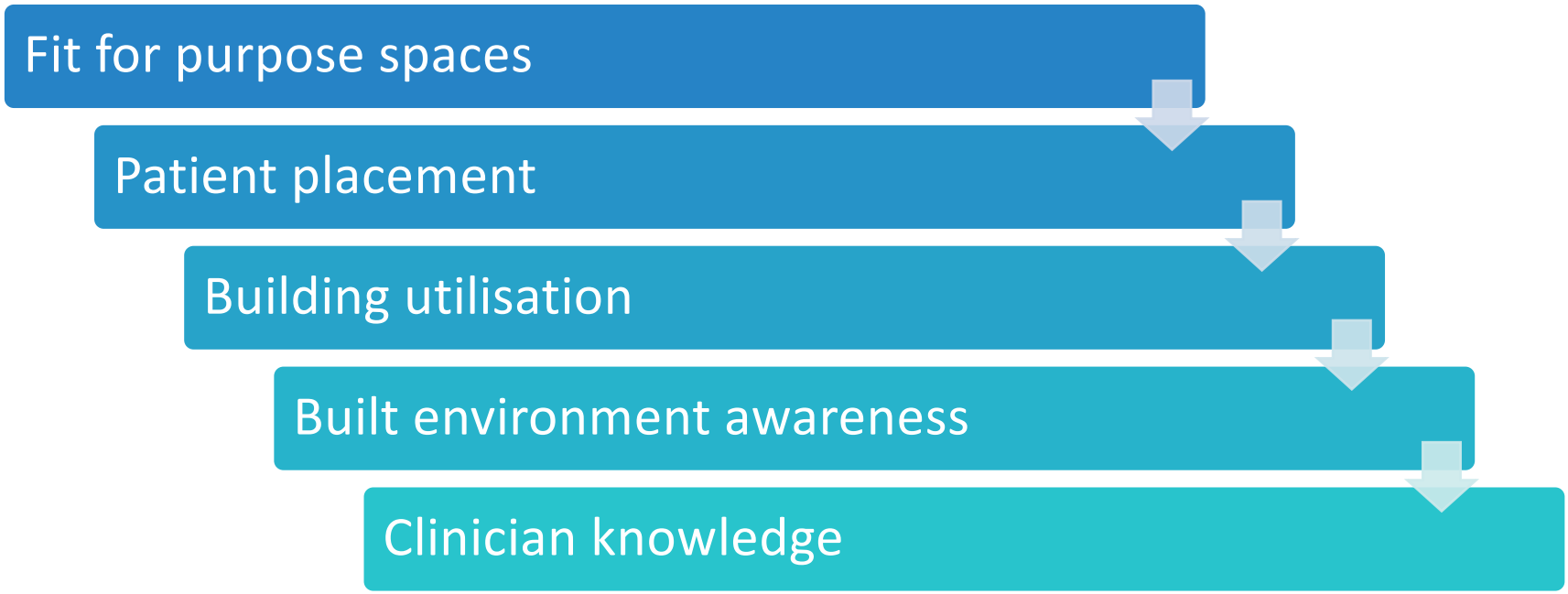
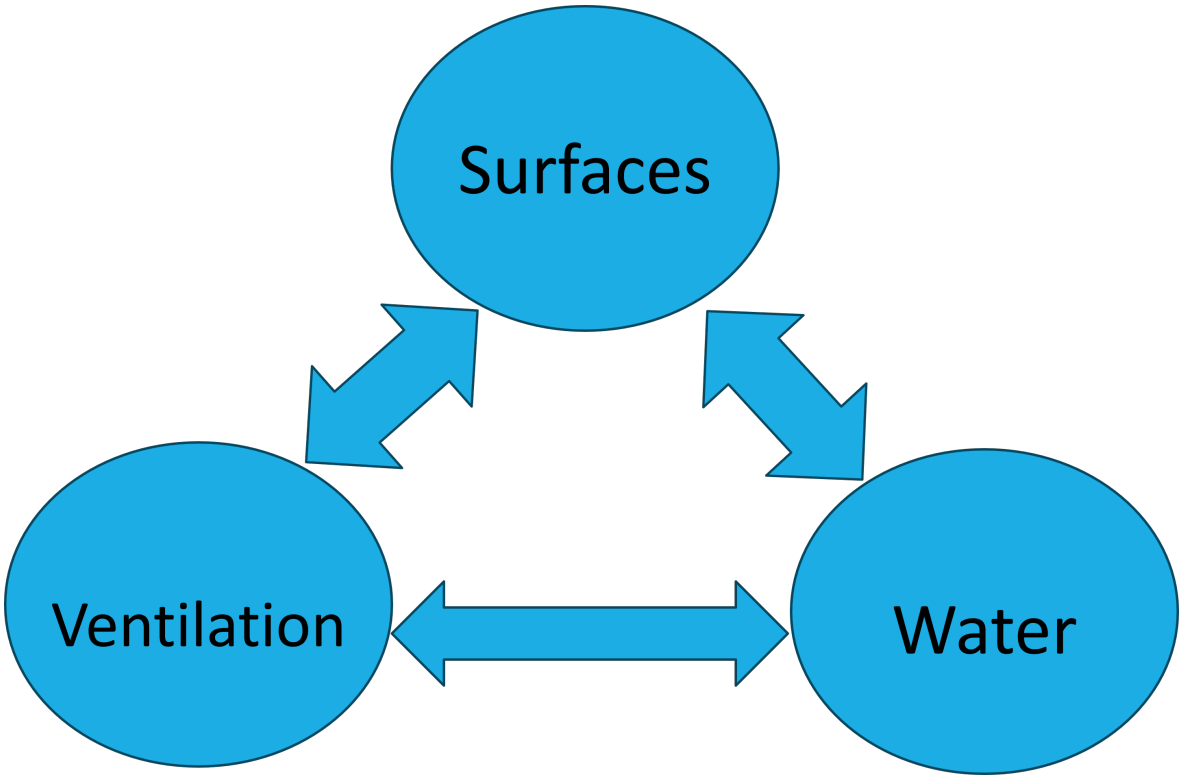
Reservoir Awareness

The Right Space to Control the Right Risk



Engineering Controls



Nothing Works in Isolation

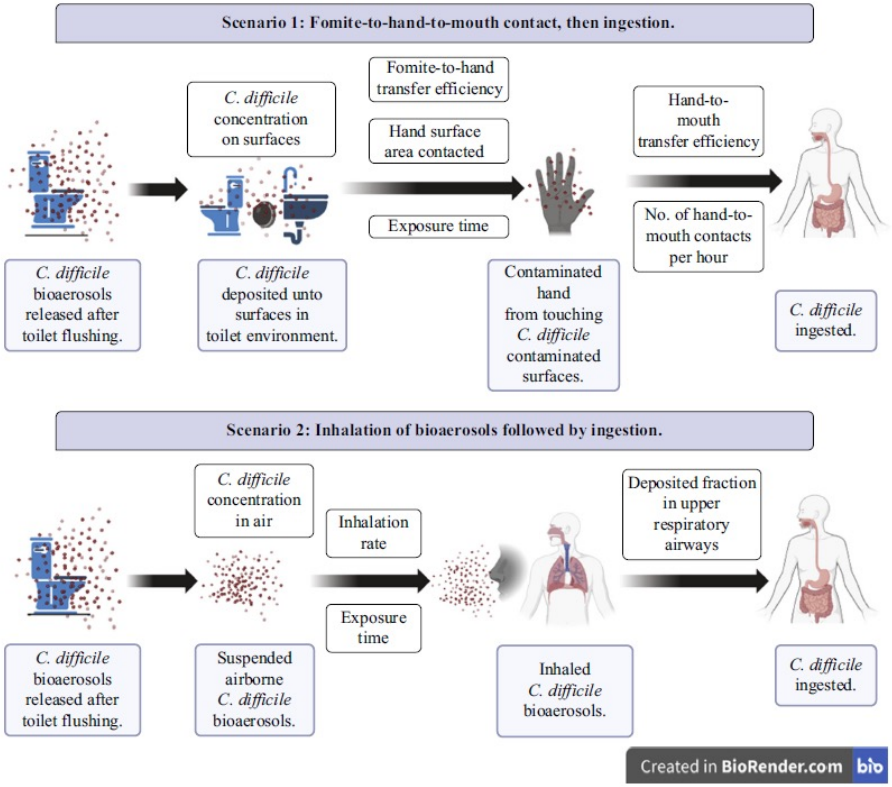
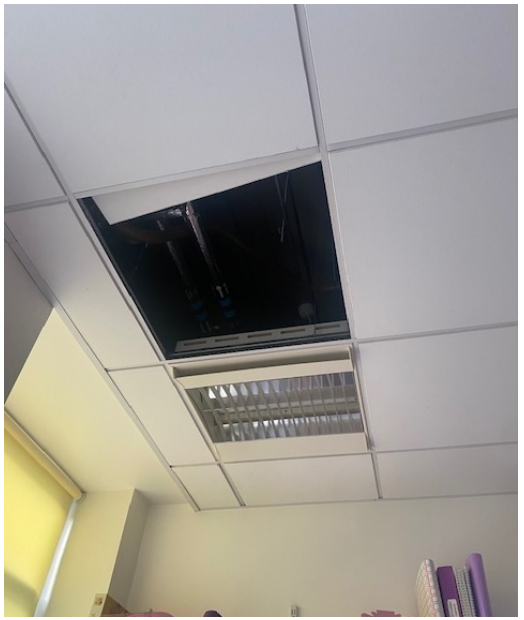


Figure 1. Exposure scenarios for *Clostridioides difficile* transmission via toilet plume bioaerosols.

Design Basics Matter

E.N. Paddy et al. Journal of Hospital Infection 159 (2025)



Seeing is Believing

Figure 1. Left: air sampler setup and use with the tap running. Right: examples of the tryptic soy agar plates and micro-c obtained.

Contamination Events are Often Invisible

Room Type: Positive pressure ventilated lobby (PPVL)

Full protection if both doors are closed. The air is replaced at a faster rate of 10 air changes per. These rooms are used for patients that are both infectious and also susceptible to infection. These rooms are also used for high-risk infections such as measles and TB.

Corridor	Lobby / anti-chamber	Cubicle		Outside
				

Design Interventions

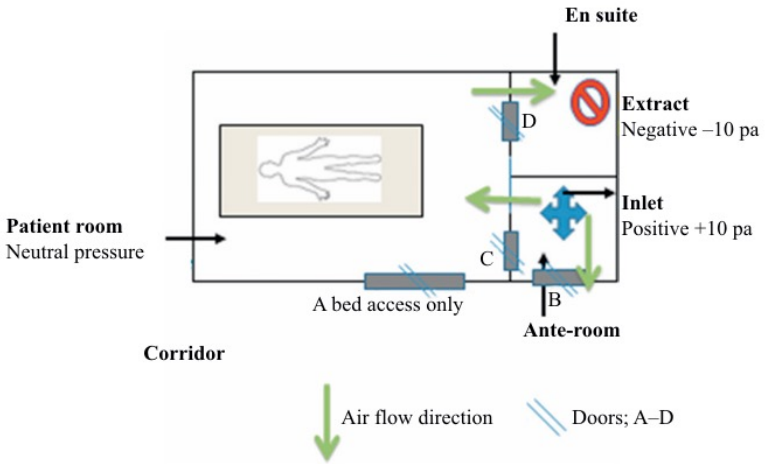
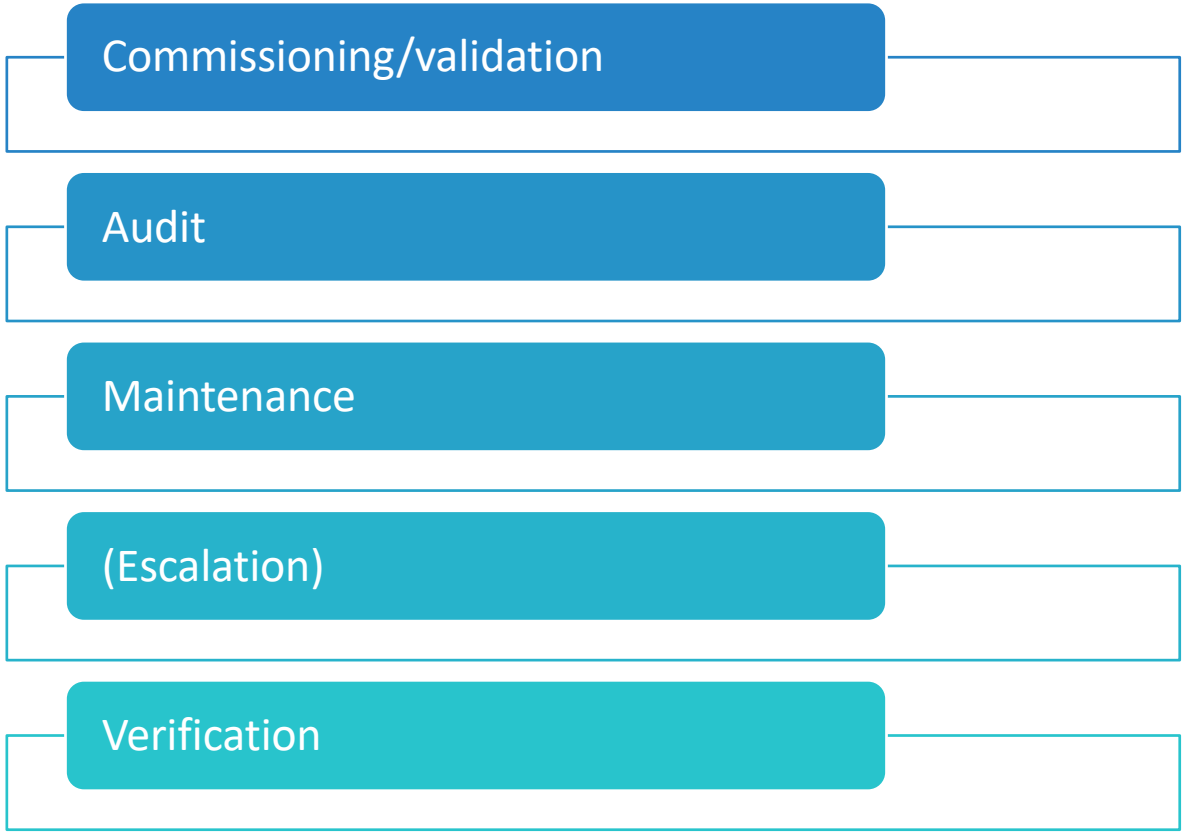


Figure 1. Layout and airflow direction of a positive-pressure ventilation lobby and neutral pressure isolation room.

Increasing Complexity Increases Monitoring Requirements

T.T. Poovelikunnel et al. Journal of Hospital Infection 106 (2020) 53-56



Stages of Engineering Control Monitoring

Behavioural Controls

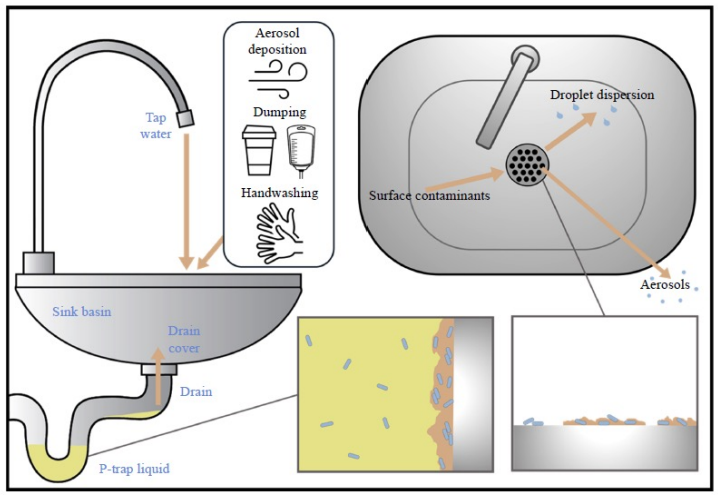


Figure 1. Schematic of sink components and bacterial colonization pathways of drain covers from various sources. Blue labels indicate sample types collected in this study.

Cruz-López F, Martínez-Meléndez A, Garza-González E. How Does Hospital Microbiota Contribute to Healthcare-Associated Infections? Microorganisms. 2023 Jan 12;11(1):192

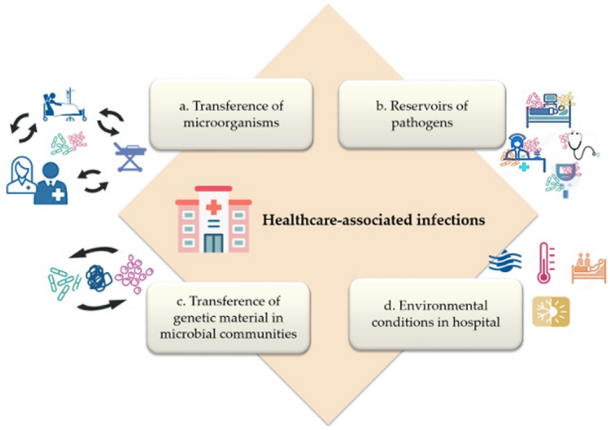


Figure 1. Factors related to healthcare-associated infections development. (**a**) transference of microorganisms between patients, healthcare workers, and hospital environmental surfaces; (**b**) hospital environmental surfaces, medical devices, healthcare workers, and patients as reservoirs of pathogens; (**c**) transference of genetic material associated with virulence, persistence, and antibiotic resistance in microbial communities; (**d**) environmental conditions, such as temperature, seasonal trend, humidity relative, and occupancy support persistence, diversity, and abundance of microorganisms on environmental surfaces.

Humans Influence their Surroundings

Health Environments Research and Design Journal (2025) V18(2) 174 - 192

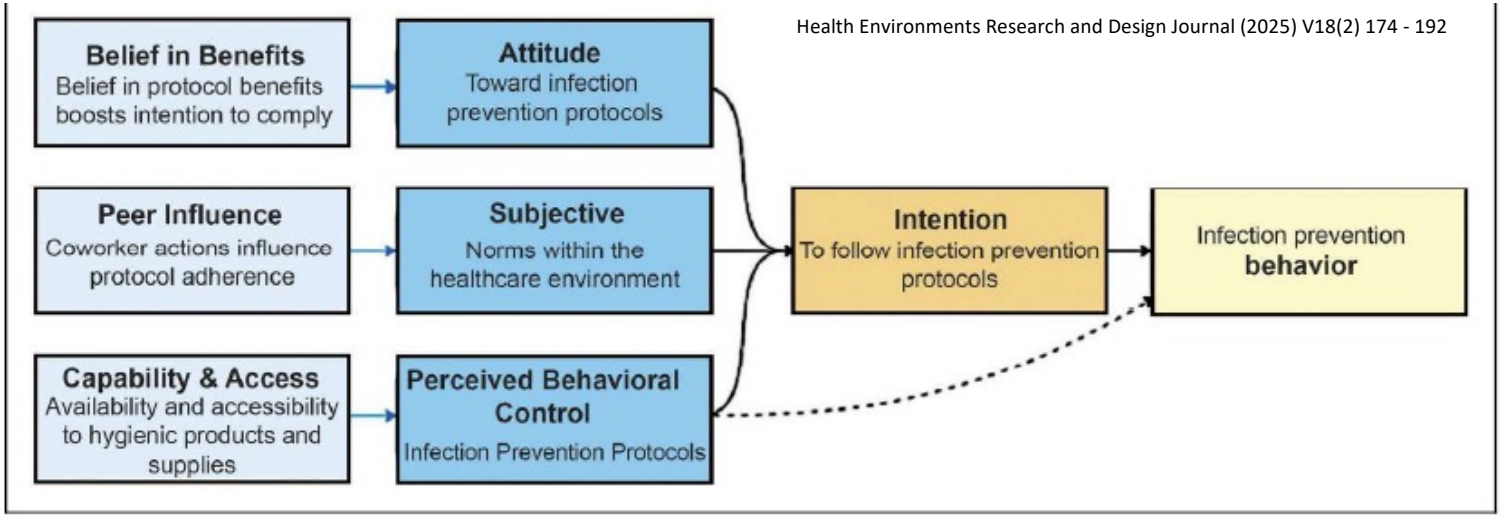
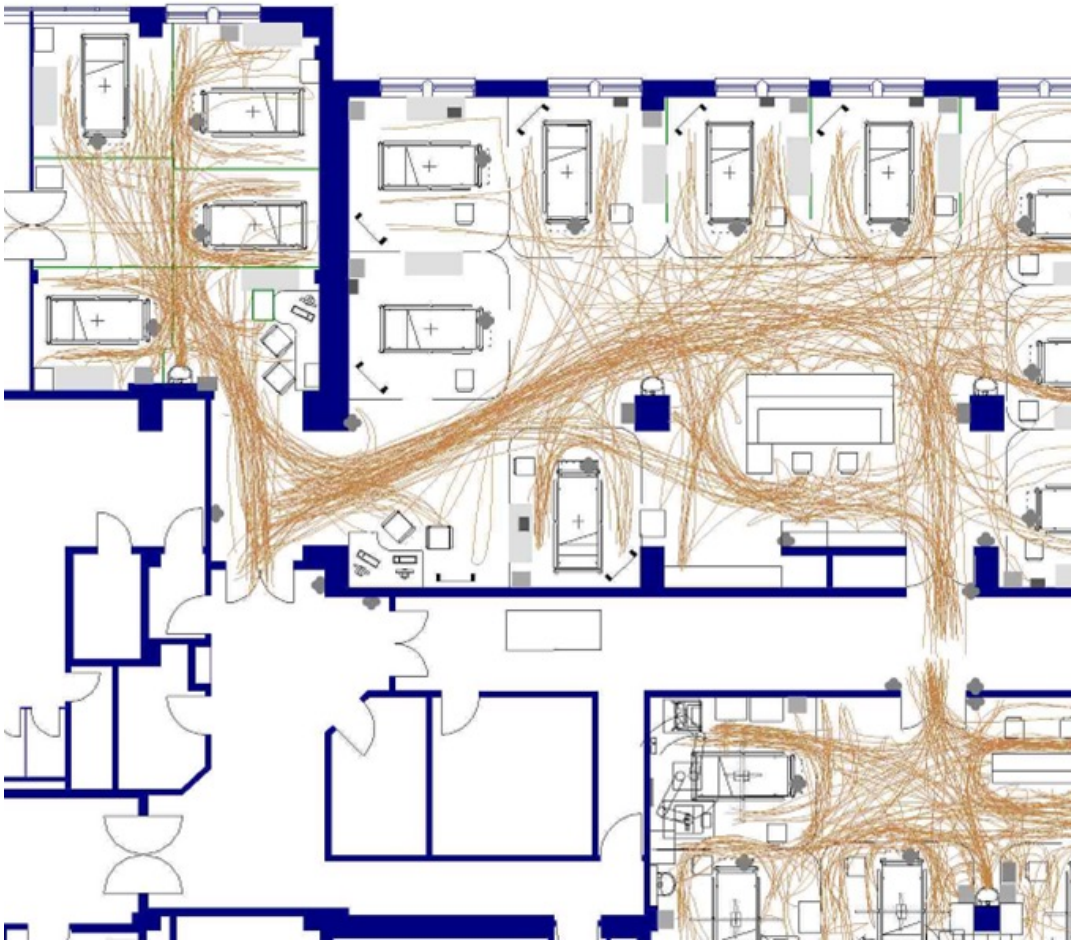


Figure 1. Relational diagram of behavioral coding syntax and TPB semantics.

Behaviour Change is Complex



Importance of Consideration of Movement

When the Best Intensions Lead to Unexpected Results

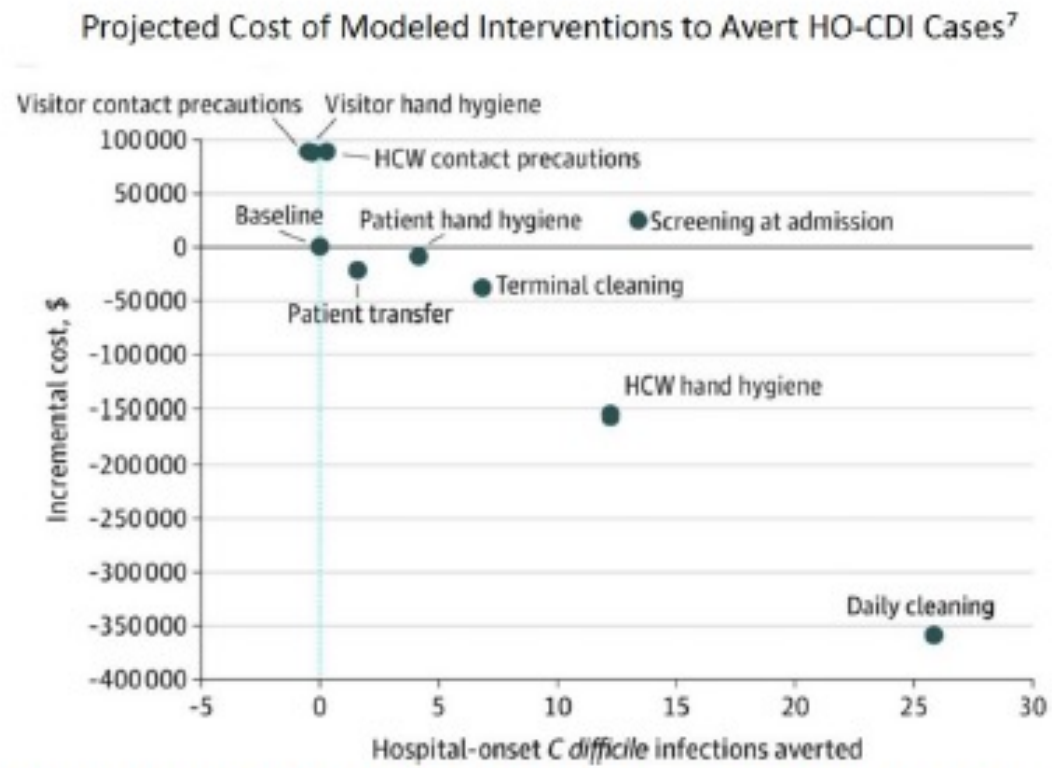
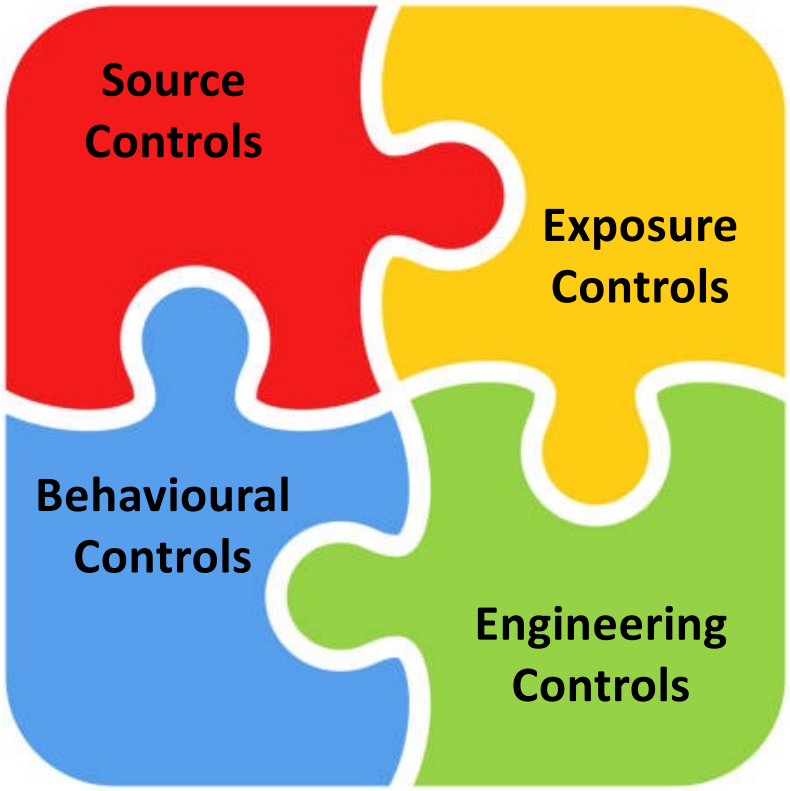


Fig. 8 Evaluation of the modeled cost (cost-avoidance) associated with interventions to mitigate HO-CDI

Not All Interventions Are Equal in All Settings

Carling *et al. Antimicrobial Resistance & Infection Control (2023) 12:94*



Know Your Toolkit

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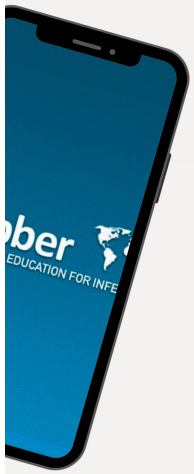

THU
23

July 23 @ 1:30 pm EDT

National and Local IPC Improvement Steps – What it Takes for Success

Presented by the International Federation of Infection Control (IFIC)
Dhouha Ammar Hamdani and **Dr. Ali Jameela**, Ministry of Health, Qatar

Free

THU
13

August 13 @ 1:30 pm EDT

What is Our Role in Preventing Infections Across Borders?

An International Federation of Infection Control (IFIC) teleclass
Dr. Gehan Fahmy, Air Force Hospitals, Egypt

Free

TUE
15

September 15 @ 2:30 pm CEST

Understanding the Role of Infection Prevention and Control in the Planetary Health Landscape

Presented by the International Federation of Infection Control (IFIC)
Prof. Dr. Walter Zingg, University Hospital Zurich, and **Dr. Ermira Tartari Bonnici**, University of Malta

Free

THU
29

October 29 @ 1:30 pm EDT

Leveraging Artificial Intelligence to Transform Infection Prevention and Control: Evidence,

Full event details and registration: at https://webbertraining.com/

www.webbertraining.com

THU
9

July 9 @ 1:30 pm EDT

Mycobacterium tuberculosis Transmission in Healthcare Settings

Prof. Michael Klompas, Harvard University

Free

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16

July 16 @ 1:30 pm EDT

LTC Preparedness for the Next Pandemic Part 2 – Getting Ready

Dr. James Ayukekbong, Editor-in-Chief, Canadian Journal of Infection Control

Free

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23

July 23 @ 1:30 pm EDT

National and Local IPC Improvement Steps – What it Takes for Success

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Dhouha Ammar Hamdani and **Dr. Ali Jameela**, Ministry of Health, Qatar

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August 2026

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13

August 13 @ 1:30 pm EDT

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