# From Drain to Patient:
# Unravelling the Sink-Pathogen Connection in Critical Care

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# Acknowledgement of country


*I acknowledge the traditional custodians of the lands on which we are meeting on today, the Gadigal people of the Great Eora nation, and the Awabakal people, who are the traditional custodians of the lands on where I live and work.*

*I pay my respects to their Elders past and present and extend that welcome to anyone present today who identify as Aboriginal or Torre Strait Islander.*

*Sovereignty has never been ceded. It always was and always will be, Aboriginal land.*

# No conflicts of interest to declare

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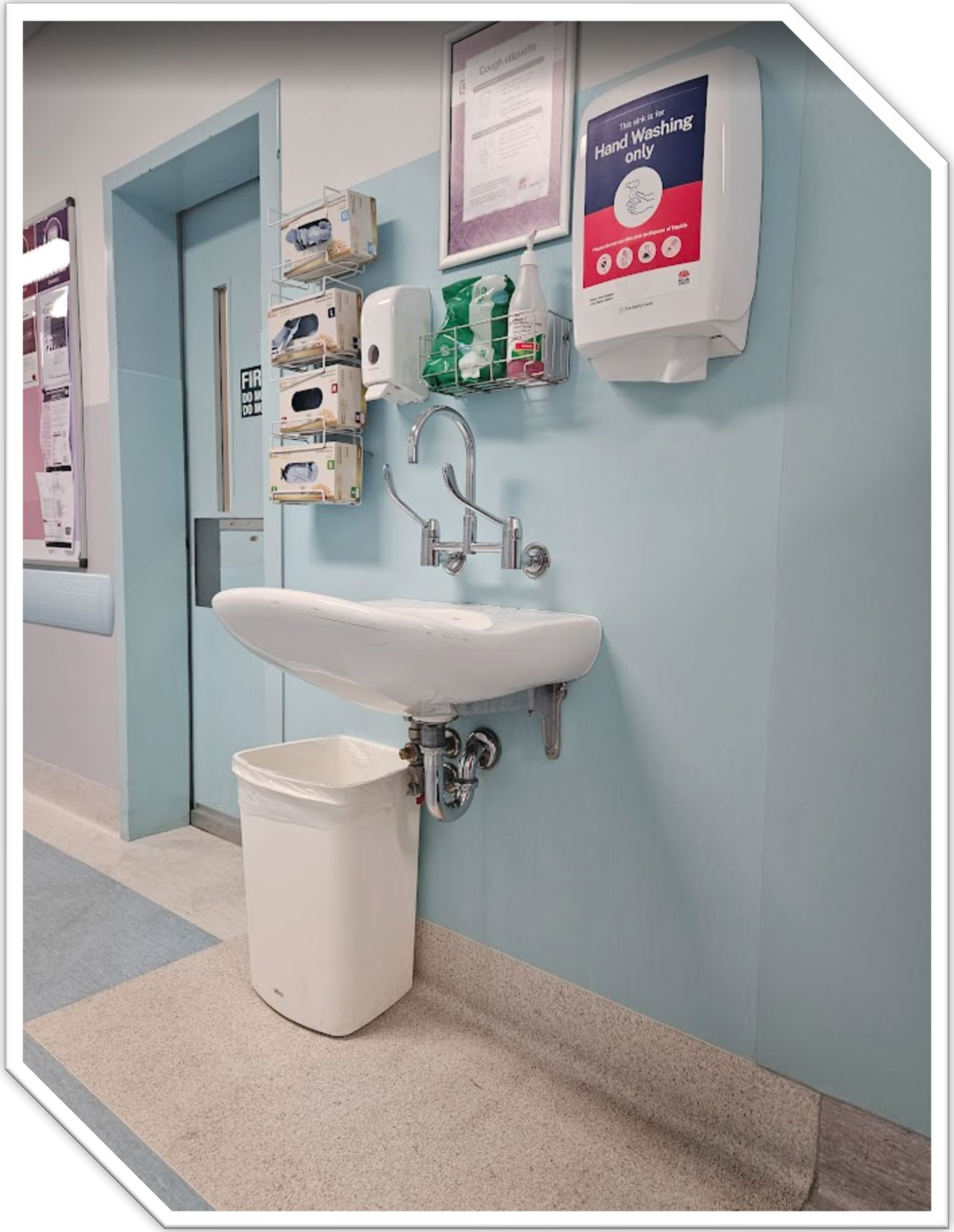
1. Clinical impact

2. Routes of transmission

3. Mitigation strategies



# Part 1: Clinical impact

Available online at www.sciencedirect.com

Journal of Hospital Infection

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

ELSEVIER

Healthcare Infection Society

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Antimicrobial

*Clinical Infectious Diseases*

REVIEW ARTICLE

**CPE only. 27 outbreaks, 1996 - 2017**

The Hospital Water Environment as a Reservoir for

Current Infectious Disease Reports (2018) 20: 42
https://doi.org/10.1007/s11908-018-0648-3

HEALTHCARE ASSOCIATED INFECTIONS (G BEARMAN AND D M
SECTION EDITORS)

**All pathogens. 43 outbreaks, 2012 - 2017**

# Sink-Related Outbreaks and Mitigation Strategies in Healthcare Facilities

Leighanne O. Parkes[1] • Susy S. Hota[2,3]

Volling, et al. Open Forum Infect Dis. 2021 Feb 1 (Vol. 8, No. 2, p. ofaa590). US: Oxford University Press. PMID: 33553469

*Open Forum Infectious Diseases*

REVIEW ARTICLE

Infectious Diseases Society of America

hivma hiv medicine association

OXFORD

# Are Sink Drainage Systems a Reservoir for Hospital-Acquired Gammaproteobacteria Colonization and Infection? A Systematic Review

Cheryl Volling,[1] Narges Ahangari,[1] Jessica J. Bartoszko,[2] Brenda L. Coleman,[1] Felipe Garcia-Jeldes,[3] Alainna J. Jamal,[1] Jennie Johnstone,[1] Christopher Kandel,[1] Philipp Kohler,[4] Helena C. Maltezou,[5] Lorraine Maze dit Mieusement,[6] Nneka McKenzie,[1] Dominik Mertz,[7] Adam Monod,[1] Salman Saeed,[8] Barbara Shea,[1] Rhonda L. Stuart,[9] Sera Thomas,[1] Elizabeth Ulervk,[10] and Allison McGeer[1]

- 52 studies implicating sink drainage systems as a reservoir for Gammaproteobacterial colonisation or infection
- Causality tool used to summarise the evidence
- **No single study provided convincing evidence across all causality domains**

Fucini, et al. J Hosp Inf. 2023 Sep 1;139:99-105. PMID: 37308060

## Sinks in patient rooms in ICUs are associated with higher rates of hospital-acquired infection: a retrospective analysis of 552 ICUs

Healthcare Infection Society

| | |
|---|---|
| **Design** | Retrospective analysis of surveillance data from the German nosocomial infection surveillance system (KISS) |
| **Population** | 1 700 000 Patients admitted to 552 German ICUs |
| **Exposure/ Comparator** | ICU with sinks in patient room (either multi-bedded or single or both), n=472 (85.5%)<br>ICUs without sinks in patient rooms, n=80 (14.5%) |
| **Outcome** | Primary: HAI (LRTI, PBSI, UTI) rates associated with any pathogen<br>Secondary: HAI-PA rates |

# Fucini, et al. J Hosp Inf. 2023 Sep 1;139:99-105. PMID: 37308060

**Table III**

Infection rates and incidence rate ratio (IRR) of hospital-acquired infections (HAI) and HAI caused by *Pseudomonas aeruginosa* (HAI-PA) across groups

| Outcome | No-sink group (N=80) | | Sink group (N=472) | | Poisson regression model[b] | | | |
|---|---|---|---|---|---|---|---|---|
| | Pooled mean (95% CI) /sum | Median (IQR) | Pooled mean (95% CI) /sum | Median (IQR) | P-value[a] | Crude IRR[b] | 95% CI | *P*-value (type III) |
| HAI | | | | | | | | |
| HAI | 3.20 (3.08–3.32) | 2.70 (1.28–4.03) | 3.97 (3.92–4.03) | 3.27 (1.74–5.27) | 0.031 | 1.24 | (1.03–1.50) | 0.019 |
| LRTI | 1.73 (1.65–1.82) | 1.33 (0.60–2.44) | 1.97 (1.93–2.00) | 1.56 (0.74–2.66) | 0.262 | 1.14 | (0.92–1.40) | 0.215 |
| PBSI | 0.62 (0.57–0.65) | 0.40 (0.11–0.77) | 0.89 (0.87–0.92) | 0.68 (0.26–1.16) | 0.003 | 1.44 | (1.09–1.91) | 0.006 |
| UTI | 0.71 (0.65–0.76) | 0.44 (0.15–0.976) | 1.04 (1.00–1.06) | 0.63 (0.21–1.40) | 0.033 | 1.47 | (1.15–1.87) | 0.001 |
| HAI-PA | | | | | | | | |
| HAI-PA | 0.34 (0.32–0.38) | 0.25 (0.07–0.4) | 0.43 (0.41–0.45) | 0.29 (0.1–0.54) | 0.065 | 1.27 | (0.96–1.68) | 0.079 |
| LRTI-PA | 0.18 (0.15–0.21) | 0.11 (0–0.26) | 0.24 (0.22–0.25) | 0.15 (0–0.32) | 0.104 | 1.34 | (1.00–1.80) | 0.034 |
| PBSI-PA | 0.017 (0.010–0.029) | 0 (0–0) | 0.026 (0.022–0.031) | 0 (0–0) | 0.011 | 1.49 | (0.60–3.72) | 0.312 |
| UTI-PA | 0.12 (0.10–0.18 | 0.04 (0–0.15) | 0.16 (0.15–0.17) | 0.08 (0–0.23) | 0.127 | 1.33 | (0.94–1.89) | 0.081 |

All pathogens

Pseudomonas aeruginosa

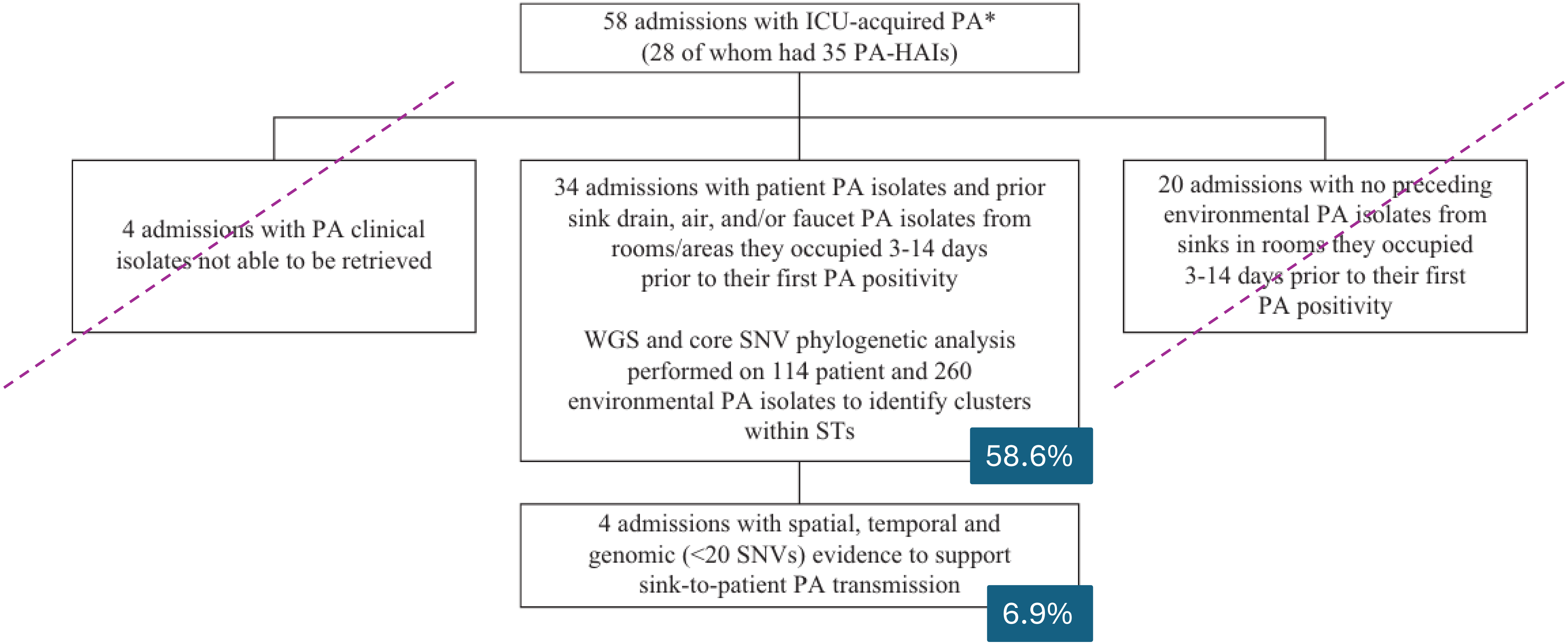
Volling C, et al. J Hosp Inf. 2024 Jun 1;148:77-86. PMID: 38554807

# Epidemiology of healthcare-associated Pseudomonas aeruginosa in intensive care units: are sink drains to blame?

Healthcare Infection Society

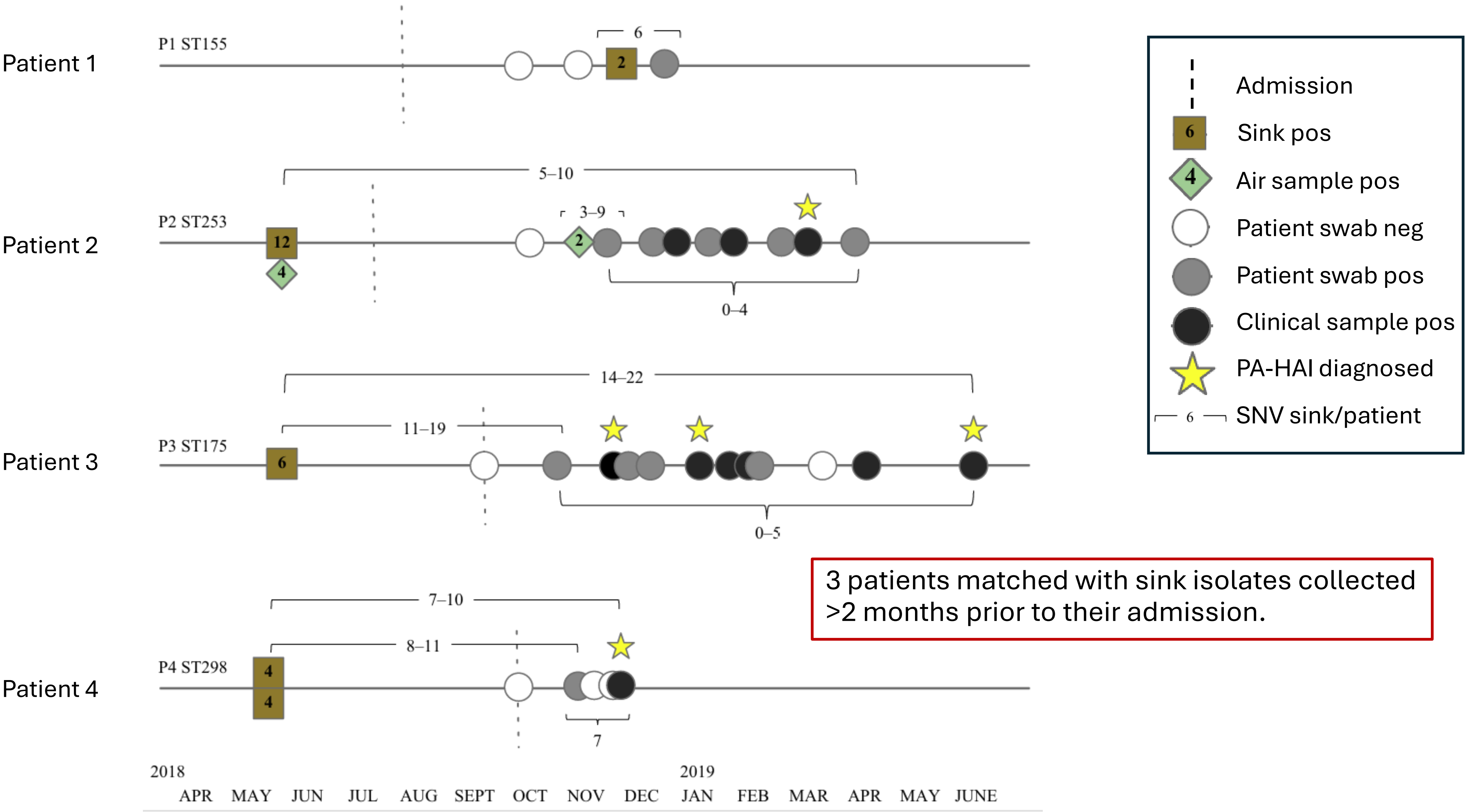
| | |
|---|---|
| Timeline | 14 months, Dec 2017 – February 2019. |
| **D**esign & **P**opulation | Prospective cohort study 6 ICUs in Canada. 3795 patients, 4263 ICU admissions |
| Patient sampling & WGS | 1. *P. aeruginosa* (PA) isolated from clinical samples (> 3 days post ICU admission)<br>2. ICU admission swabs were retrieved for PA screening if PA identified clinically<br>3. All rectal swabs collected > 48 hours post admission were screened for PA |
| Sink sampling & WGS | Sink drain tailpiece, faucet, and air samples collected from 97 sinks (from 59% bedspaces/rooms), x3 prior to patient data collection and x4 after. WGS where relevant* |
| **O**utcome | **Sink to patient PA transmission:** ICU-acquired PA with <20 SNV different between patient and sink isolates. |

# Volling C, et al. J Hosp Inf. 2024 Jun 1;148:77-86. PMID: 38554807




At least 7% of all ICU acquired *Pseudomonas* was acquired from sinks. 50% of those with ICU acquired PA had infections, and the mortality rate was > 30%.

# Volling C, et al. J Hosp Inf. 2024 Jun 1;148:77-86. PMID: 38554807




3 patients matched with sink isolates collected >2 months prior to their admission.

# Part 2: Routes of transmission

Najjar-Debbiny, et al. Am J Infect Cont. 2023 Nov 1;51(11):1279-81. PMID: 37499760

# How do they get from A to B?

835 environmental samples collected from 20 hospital departments

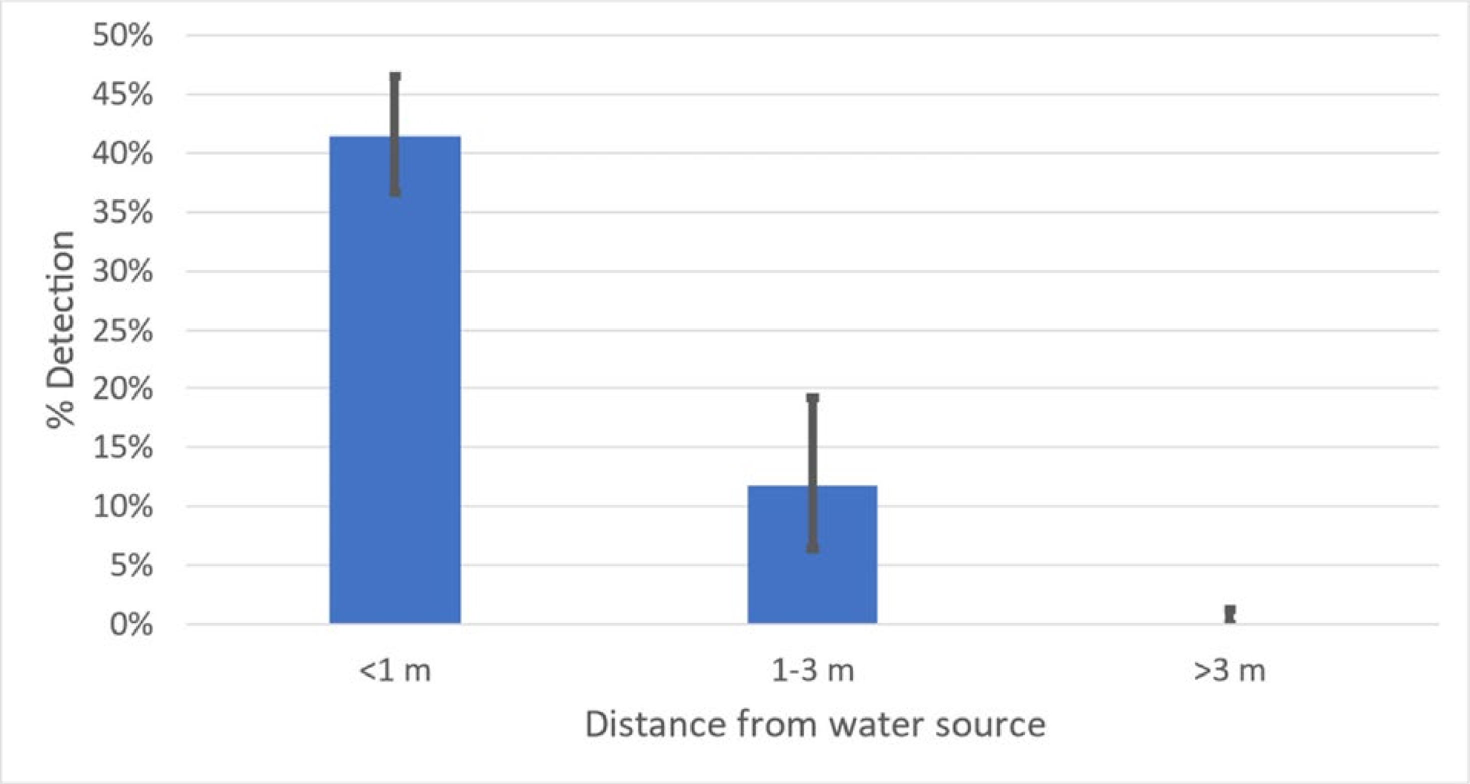



**Fig. 2.** Distribution of carbapenemase-producing Enterobacteriaceae (CPE) in hospital water environments based on distance from water sources.

## Gestrich, et al. Infect Control Hosp Epidemiol. 2018 Dec;39(12):1467-9. PMID: 30526714

**Table 1.** Odds Ratios for Sink Design Features Associated with Dispersal of Fluorescent Gel from the Sink Drain by Running Water

| Characteristic | Odds Ratio | 95% Confidence Interval | *P* Value |
|---|---|---|---|
| Bowl depth (cm)[a] | 0.69 | 0.59–0.79 | .00 |
| Faucet flow indirect versus direct relative to strainer | 1.28 | 0.58–2.88 | .54 |
| Faucet goose neck versus other design | 0.78 | 0.29–2.10 | .62 |
| Automatic versus manual sink | 0.73 | 0.30–1.74 | .48 |
| Bowl circumference (cm) | 1.01 | 0.99–1.04 | .33 |

[a]Vertical distance from the strainer to the sink edge.

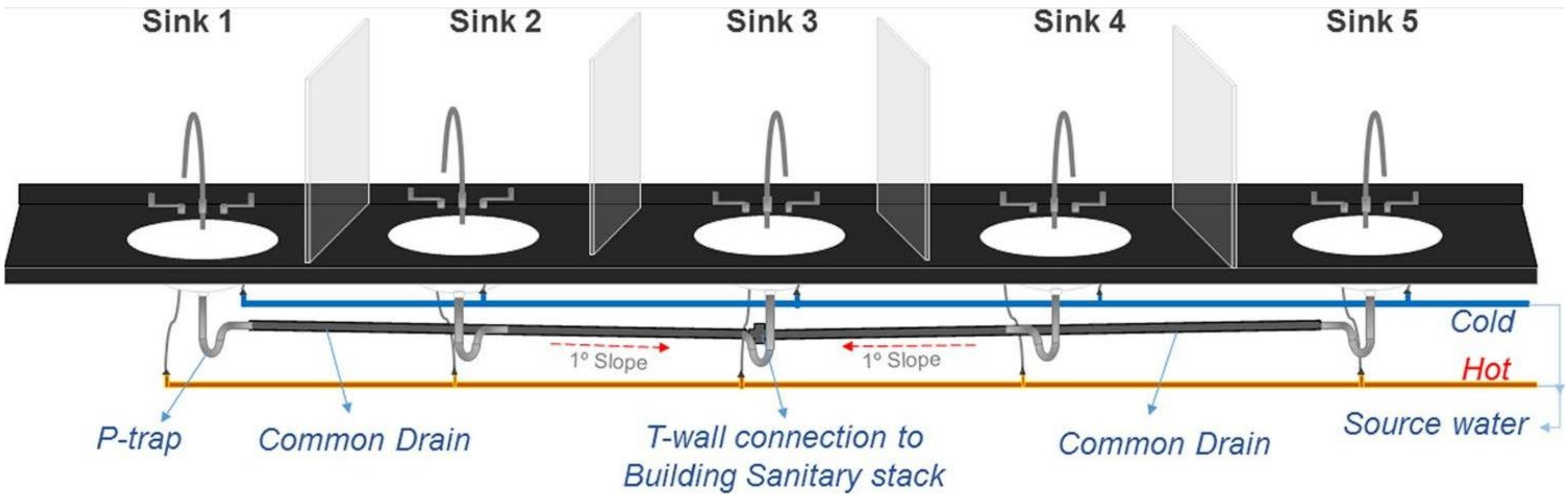
- Shallow sink increases splash
- Faucet directly over drain – mixed results.
- Impacted by water flow and drainage

## Aranega-Bou, et al. J Hosp Infect. 2019 May 1;102(1):63-9. PMID: 30571992

**Table I**
Dispersal of carbapenem-resistant Enterobacteriaceae (CRE) from waste traps artificially seeded with CRE

| | Fast drainage | | Slow drainage | |
|---|---|---|---|---|
| | Active sampling Cyclone sampler (cfu/400 L air) | Passive sampling Settle plates (total sfu) | Active sampling Cyclone sampler (cfu/400 L air) | Passive sampling Settle plates (total sfu) |
| Drain underneath faucet | 0[a] | 0 | $2.3 \times 10^3 \pm 1.8 \times 10^3$ | $1.4 \times 10^2 \pm 6.1 \times 10^1$ |
| Drain at rear | 0 | 0 | 0[a] | 0 |

# From the sink to the patient




- Biofilm growth from P-trap to grate within 7 days when **nutrients** added[1]
- **Sink grate** biofilm resulted in environmental contamination (droplet rather than aerosol)[1]
- P-trap colonisation occurs via retrograde transmission along common pipes[1]
- Reducing splash has been demonstrated to reduce contamination and control outbreaks[2,3]
- **Droplet-, rather than aerosol-mediated dispersion is the primary mechanism of bacterial transmission from contaminated hand wash basins**[4]


1. Kotay, et al. Appl Environ Microbiol. 2017;83(8):e03327-16.
2. PloS one. 2023;18(3):e0282090.
3. Infect Control Hosp Epidemiol. 2009;30(1):25-33.
4. Kotay, et al. Appl Environ Microbiol. 2019 Jan 15;85(2):e01997-18.

# When everything goes wrong …

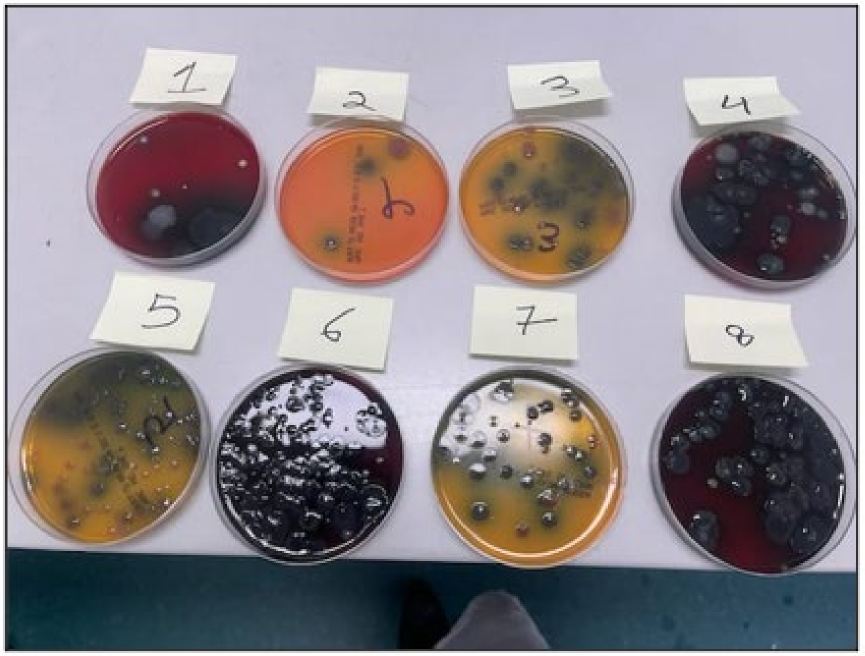
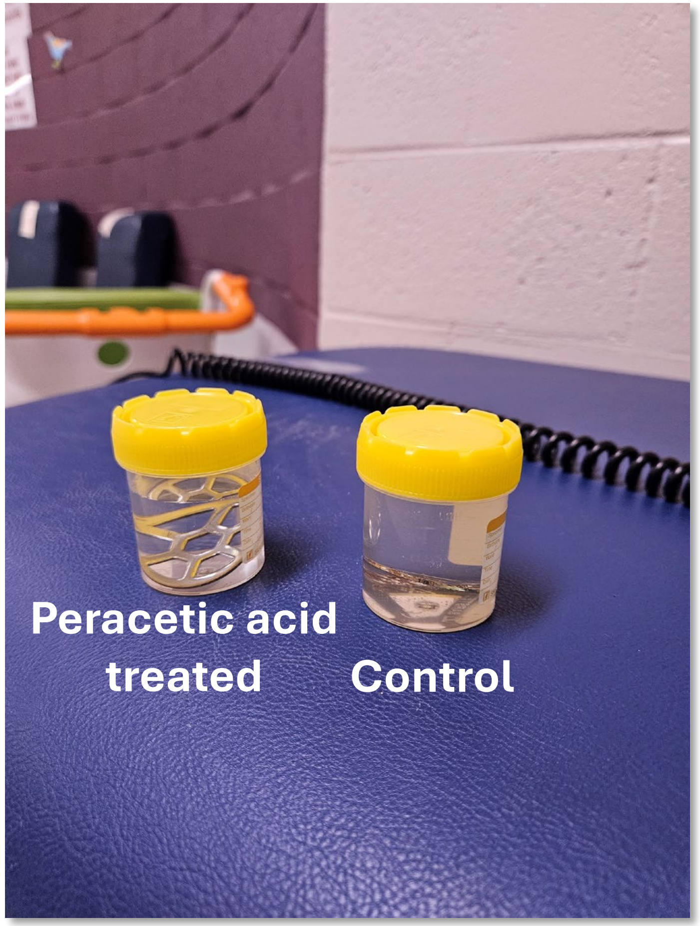


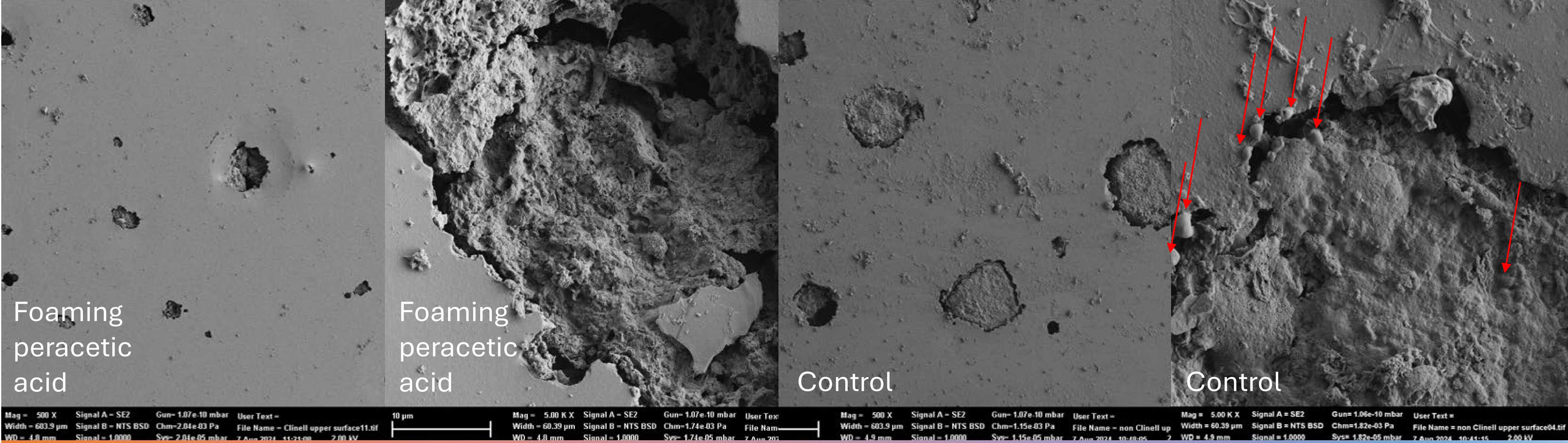

*Figure 3a (left): Pilot experimental study using horse blood and MacConkey agar as settle plates during undisturbed water faucet use for 60 seconds; Figure 3b (right): Growth of bacterial colonies following 48 hours incubation, indicating contamination following indirect exposure to undisturbed faucet water flow.*

Unpublished pilot experiment, Browning & Naqvi. HNELHD

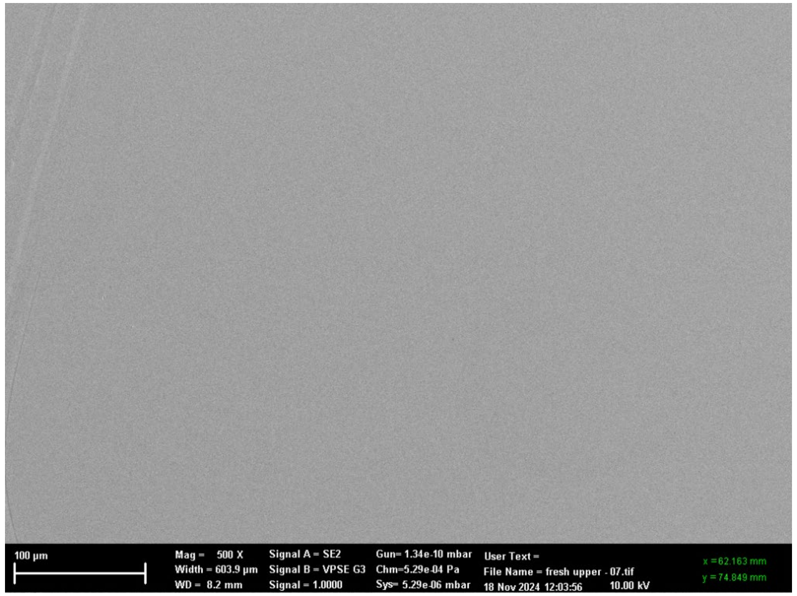
# Scanning electron microscopy








- Micro corrosion / pits deeper in PA sample
- No bacteria visible on pit perimeters or within pits in PA sample
- Pits appear deeper and hollowed out in PA sample
- Pits not present when an unused replica was scanned



Source: Unpublished pilot study. Browning, et al.

# Can we rely on sink models to mimic transmission routes in clinical settings?

Gormley, et al. PLoS ONE. 2017 Feb 10;12(2):e0171556. PMID: 28187135
Gormley, et al. Build Res Inf. 2019 May 19;47(4):421-36. doi.org/10.1080/09613218.2017.1412097

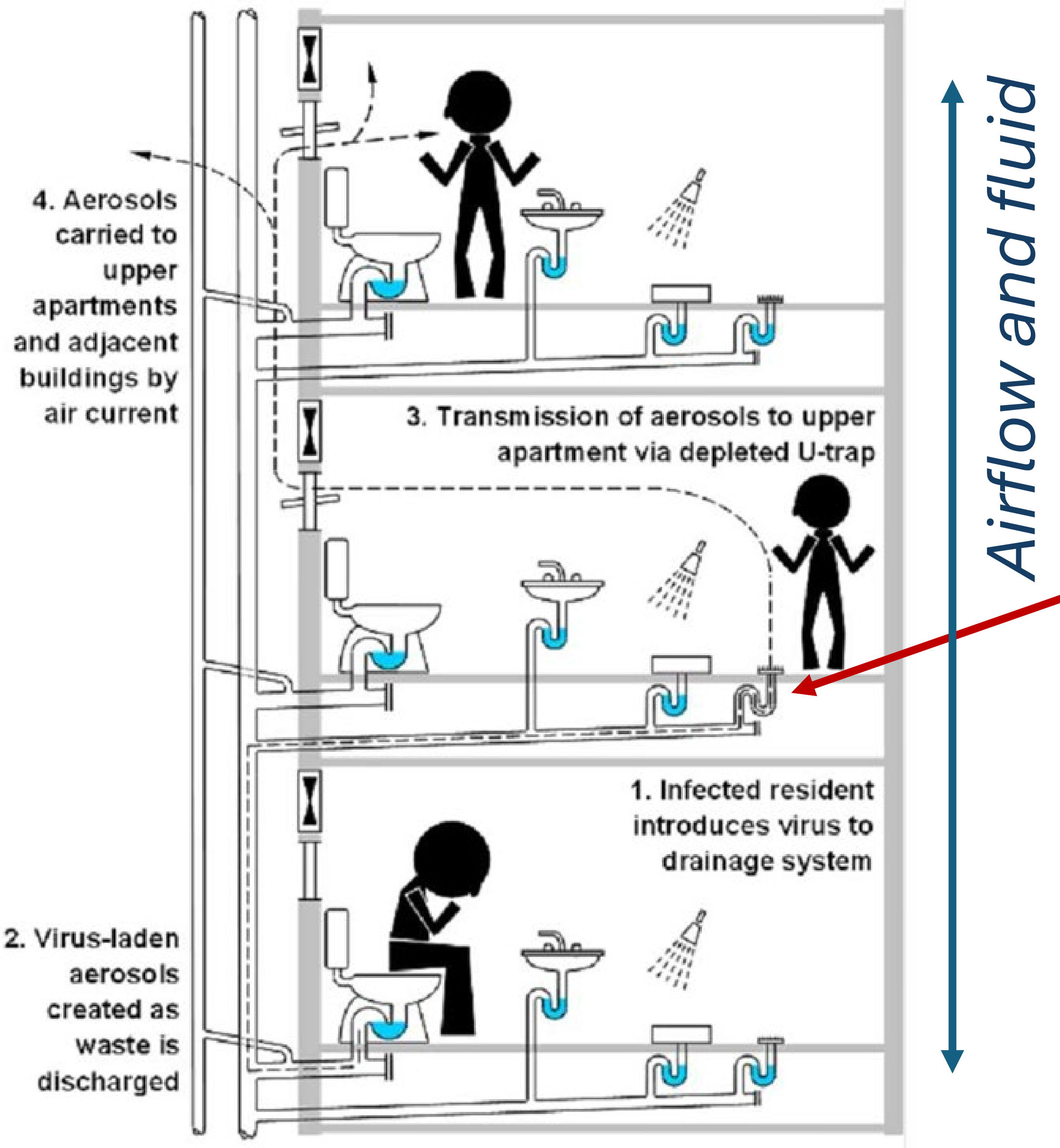



Fig 1. SARS transmission route at Amoy Gardens via the sanitary plumbing system.

- Ventilation in plumbing systems is important. Air travel is two directional, up and down
- Flushing a toilet can generate enough turbulence to aerosolise pathogens from an empty P-trap located on a different floor of the building
- Implicated in viral transmission (SARS-CoV-1) and aerosolisation of bacteria in drains

**What risk does a P trap pose when full?**

Gormley, M & Kelly, DA. Build Res Inf. 2019 May 19;47(4):421-36. doi.org/10.1080/09613218.2017.1412097

# Ventilation gone wrong.

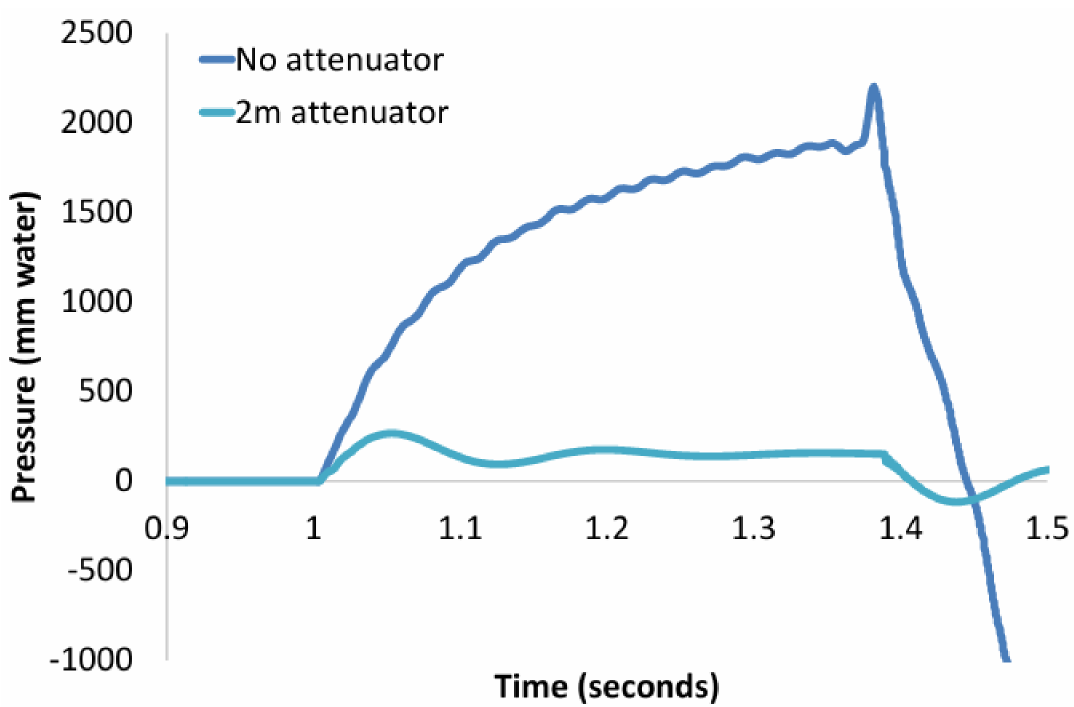
(a) (b) (c)

The effect of large pressure surge on a WC situated 3 floors from base of stack with no alleviation. (a) the pressure wave arrives at the WC and blows out the water seal; (b) the water seal is thrown out beyond the WC; (c) the water seal is completely removed from the WC.

# Part 3: Mitigation strategies

Gormley, M & Kelly, DA. Build Res Inf. 2019 May 19;47(4):421-36. doi.org/10.1080/09613218.2017.1412097

# Positive pressure attenuator (PAPA)




Would a one-way valve in the tailpipe provide some protection?

**Figure 10: AIRNET simulated pressure response of the system shown in Figure 9 showing the attenuating effect of the linear exits.**

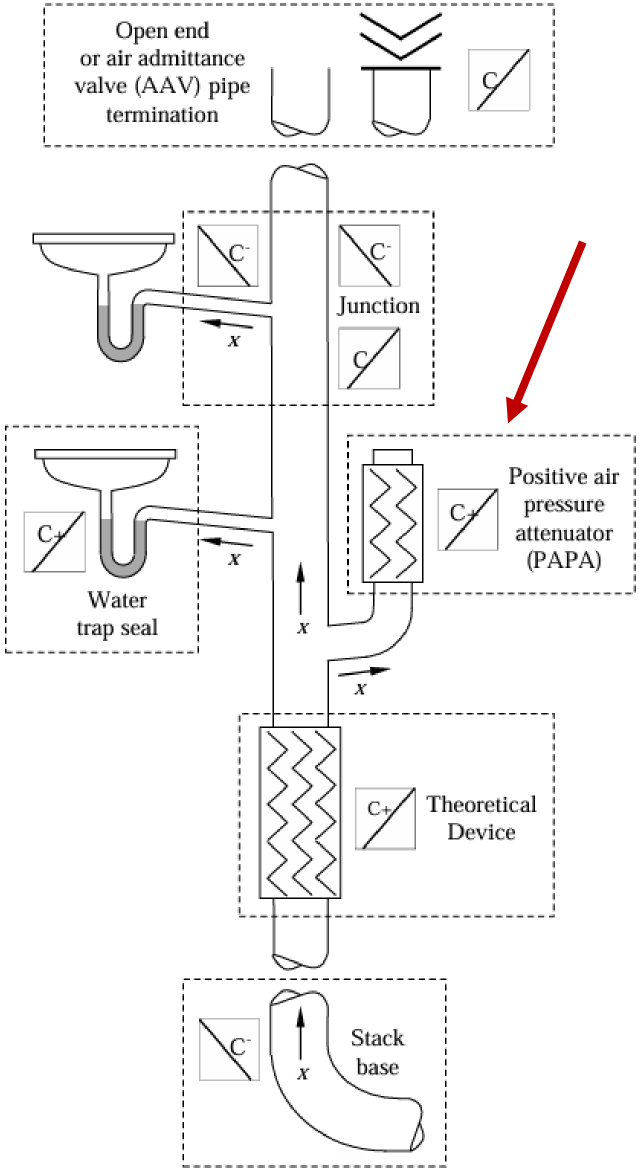



**Figure 7: Boundary conditions and available characteristics for a typical building drainage system**

Propagating pressure waves can be attenuated

Fucini, et al. J Hosp Infect. 2024 Jan 1;143:82-90. PMID: 38529781

# Sink interventions in the ICU to reduce risk of infection or colonization with Gram-negative pathogens: a systematic review of the literature

Healthcare Infection Society

| | |
|---|---|
| **Design** | Systematic review and meta-analysis including 4404 records from MEDLINE and EMBASE (May 2022) |
| **Inclusion criteria** | All studies which describe an intervention on water fixtures in patient rooms AND presented data about HAI or colonisation rates. |
| **Data collected** | Study design, population, sink (and co-) interventions, microbiological methods, and patient colonisation or infection using a pre-prepared data extraction form. Risk of bias |
| **Outcome** | 11 full-text papers included for review |

Fucini, et al. J Hosp Infect. 2024 Jan 1;143:82-90. PMID: 38529781

# Results

5 main interventions used (water filters, removal of sinks, sink drain heating and vibration devices, new taps, and hopper covers).

1. Point of use water filters may be effective in settings with high *P. aeruginosa* endemicity
2. Removing sinks from patient rooms resulted in a significant reduction in the risk of GNB acquisition
3. Heating and vibration devices - mixed results

Moderate to serious levels of bias in all studies

Evidence limited by co-interventions and unclear or short follow-up

Arbel,et al. J Hosp Infect. 2025 Feb 28:S0195-6701(25)00052-0. PMID: 40024457

# Evaluating Decontamination Interventions to Control CPE Transmission from Sinks: A Retrospective Analysis

Healthcare Infection Society

| | |
|---|---|
| **Design** | Retrospective observational analysis of data from the IPS registry at one hospital |
| **Population** | Seven CPE positive sinks, decontaminated using a standardised protocol |
| **Intervention** | Application of one of the following chemical agents: chlorine (2000 ppm, 3 L), hydrogen peroxide (3 L), hydrochloric acid (3%, 3 L), or acetic acid (20%, 250 mL).<br>Poured directly into the sink and left for 10 minutes contact time. |
| **Outcome** | Daily sink sampling for CPE positivity reveals **average time to CPE sink positivity post decontamination was 3.6 days** |

Catho, et al. Clin Microbiol Infect. 2024 Aug 1;30(8):1049-54. PMID: 38759869

# Controlling the hospital aquatic reservoir of multidrug-resistant organisms: a cross-sectional study followed by a nested randomised trial of sink decontamination

| | |
|---|---|
| **Design** | Nested RCT (1:1:1) of MDRO colonised sinks (ESBL, CPE, non-fermentative GNBs) |
| **Population** | 51 MDRO contaminated sinks in 26 clinical wards in one tertiary hospital |
| **Intervention** | Randomised to receive chemical (sodium hypochlorite), thermal disinfection (steam), or no intervention, repeated weekly for 4 weeks, after P-trap exchange |
| **Outcome** | Proportion of decontaminated sinks 7 days after the last intervention |

Catho, et al. Clin Microbiol Infect. 2024 Aug 1;30(8):1049-54. PMID: 38759869

No added benefit of repeated chemical or thermal disinfection, beyond changing sink traps

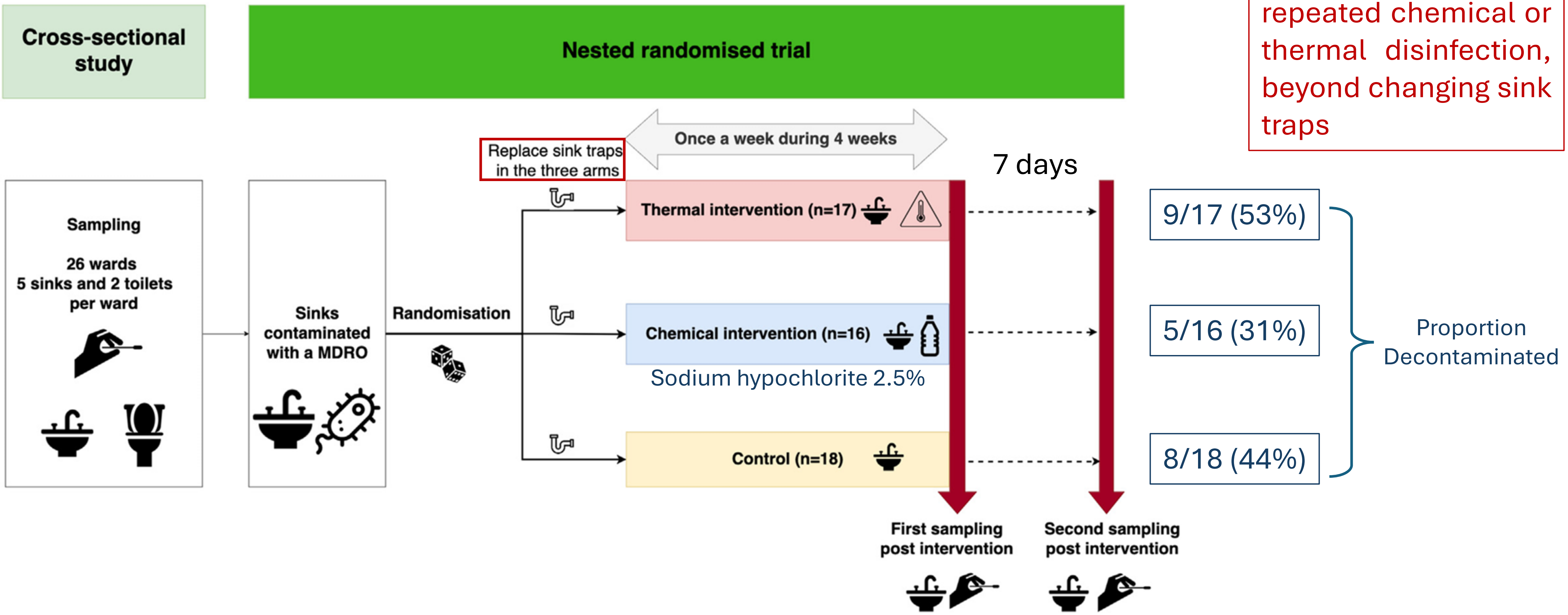



**Fig. 1.** Flowchart of the cross-sectional study and the nested randomized trial.

Ledwoch, et al. J Hosp Infect. 2020 Dec 1;106(4):757-64. PMID: 32828863

# Active ingredient and formulation matters.

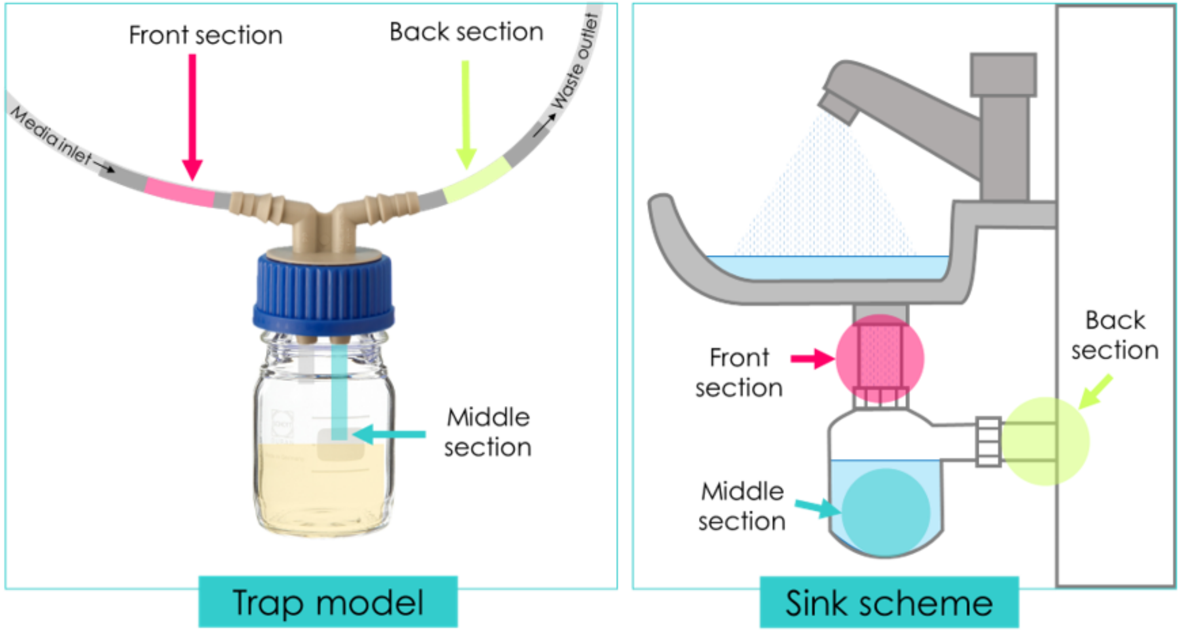



**Figure S1**. Sampling sections for trap (left) model with corresponding sections from actual sink (right).

## Biofilm recovery 4 days following x3 15 min treatments

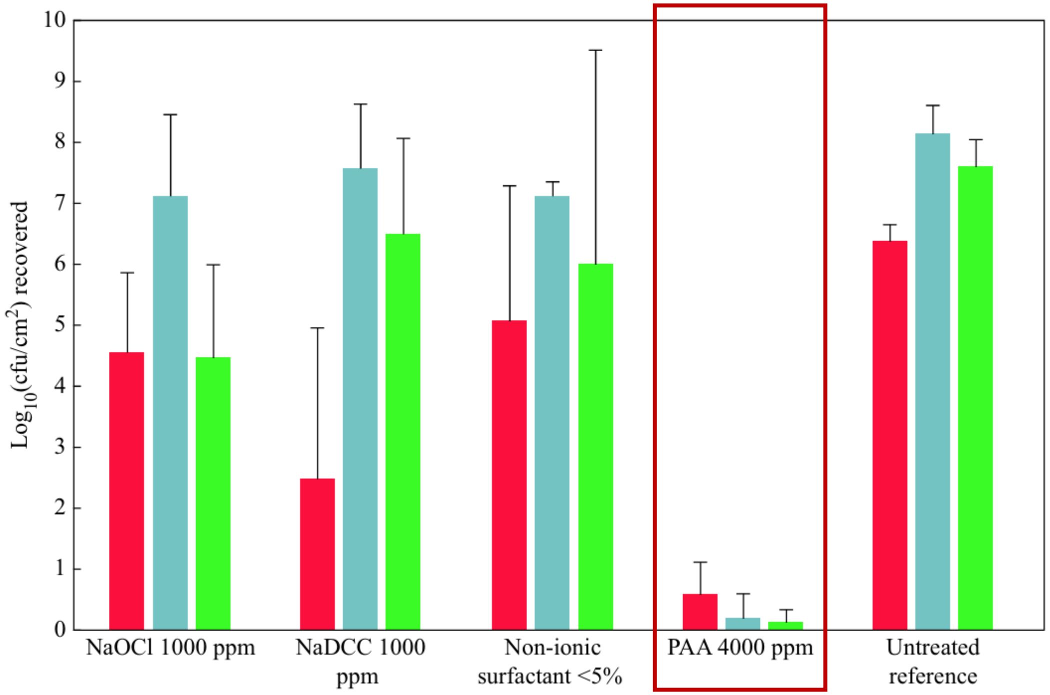
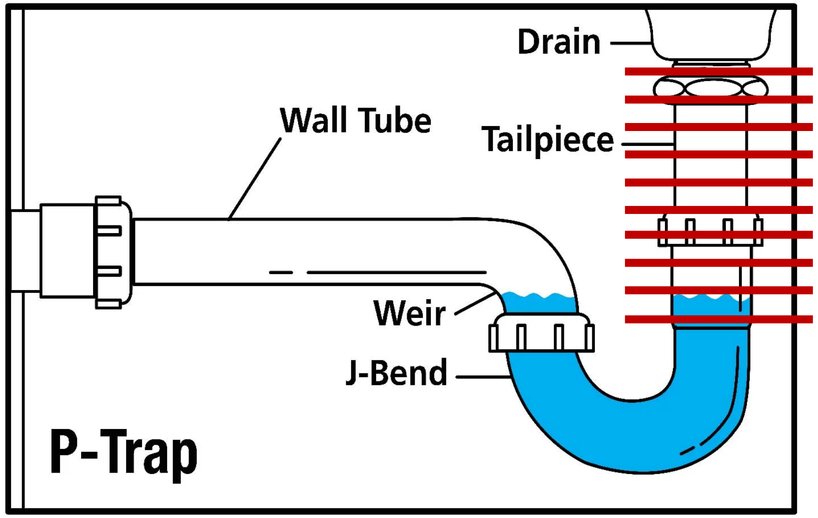


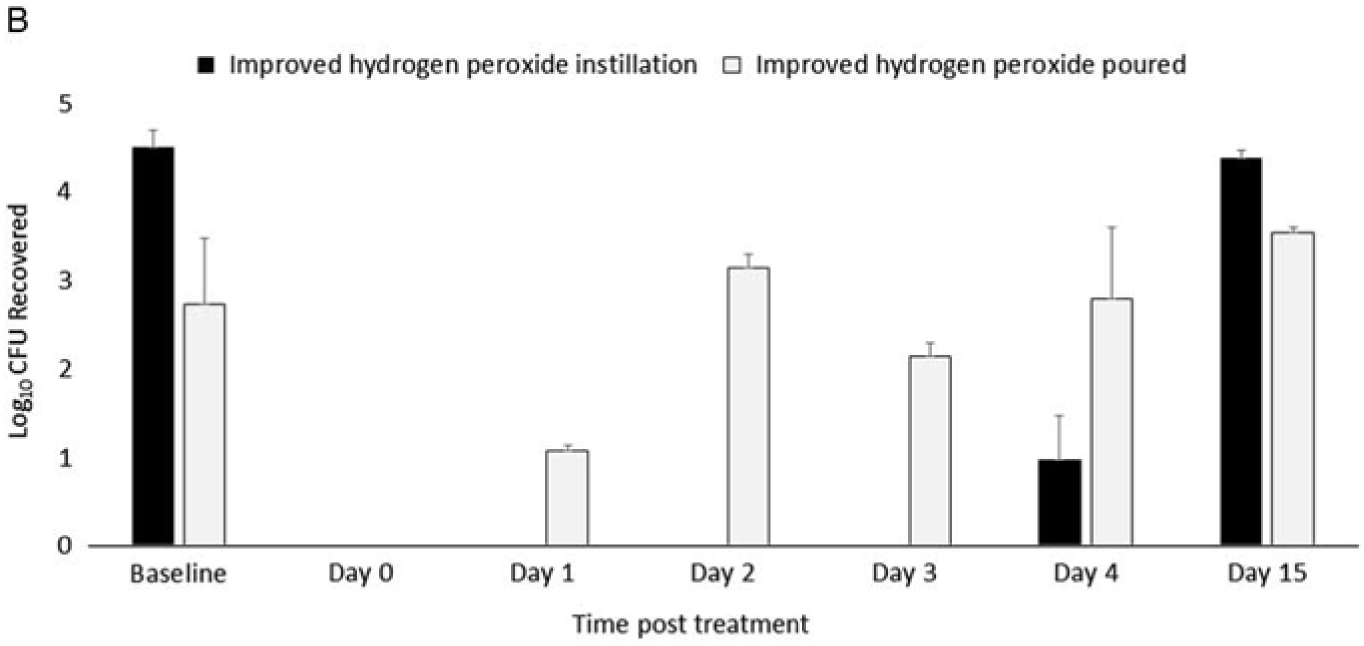

**Figure 3.** $Log_{10}$ colony-forming units (cfu)/$cm^2$ of bacteria recovered from biofilm 4 days after a series of three 15-min treatments. Red bars, front section; blue bars, middle section; green bars, back section. cfu, colony-forming unit.

Cadnum, et al. Infect Control Hosp Epidemiol. 2019 Feb;40(2):254-6. PMID: 30560752

# Use of a stop valve to enhance disinfectant exposure may improve sink drain disinfection




Red lines indicate area of the drain and tailpipe into which hydrogen peroxide was instilled and held for 1 hour using a stop valve.



Vanstokstraeten, et al. J Hosp Infect. 2024 Dec 1;154:45-52. PMID: 39341282

# Contact with contaminated surfaces is important

**Heavy contamination of tailpipe immediately after treatment with Clinell drain disinfectant**

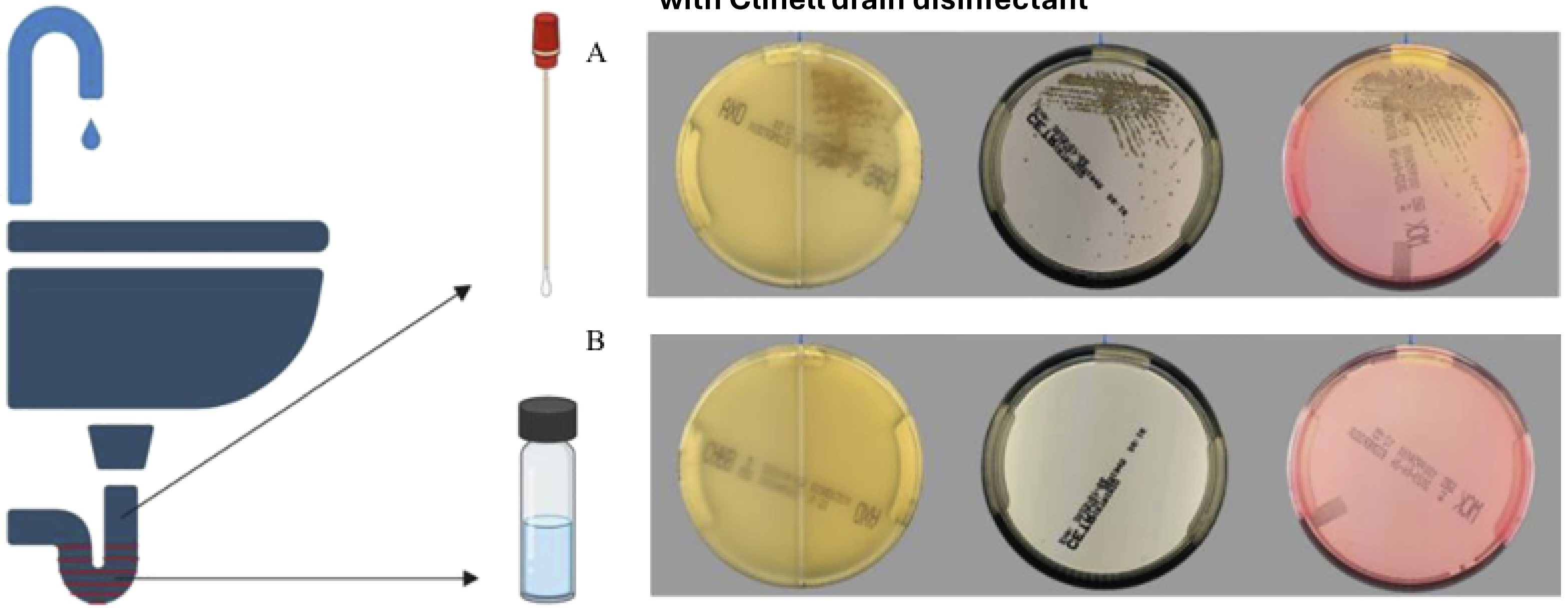



**Figure 6.** Impact of Clinell Drain Disinfectant on the cfu on Chromid Carba Smart agar, cetrimide agar, and MacConkey agar. Both samples (A and B) were taken directly after decontamination. Sample A was collected by rubbing an eSwab at 10–15 cm depth in the drain. Sample B was collected by sucking P-trap water (red lines in the figure) using a sterile suction catheter and a sterile syringe. Where sample B showed no bacterial growth after decontamination, sample A remained heavily contaminated.

*"The active ingredients of the disinfectants do not penetrate the upper section of the drainage system."*

Shikama, et al. Antimicrob Steward Healthc Epidemiol. 2024 Jan;4(1):e98. PMID: 38836042

## Daily application of a foaming 0.1% sodium hypochlorite resulted in a reduction in CPE colonised sink/drain surfaces, but only for sinks deemed to be low risk (L) of having nutrients routinely discarded down the drain

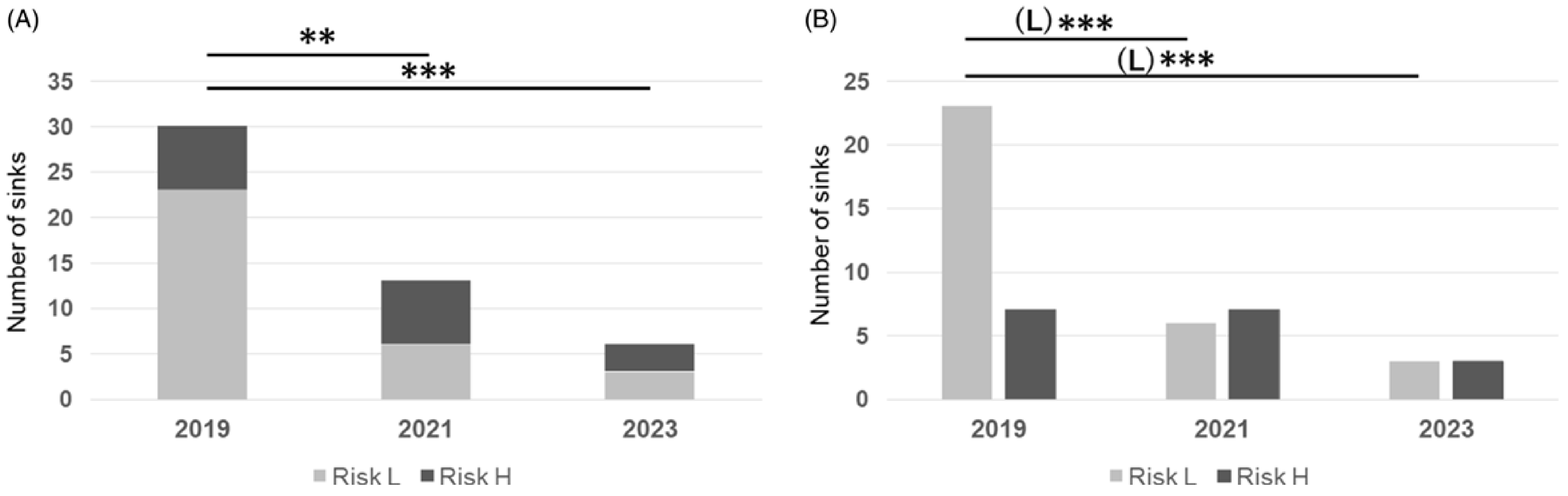
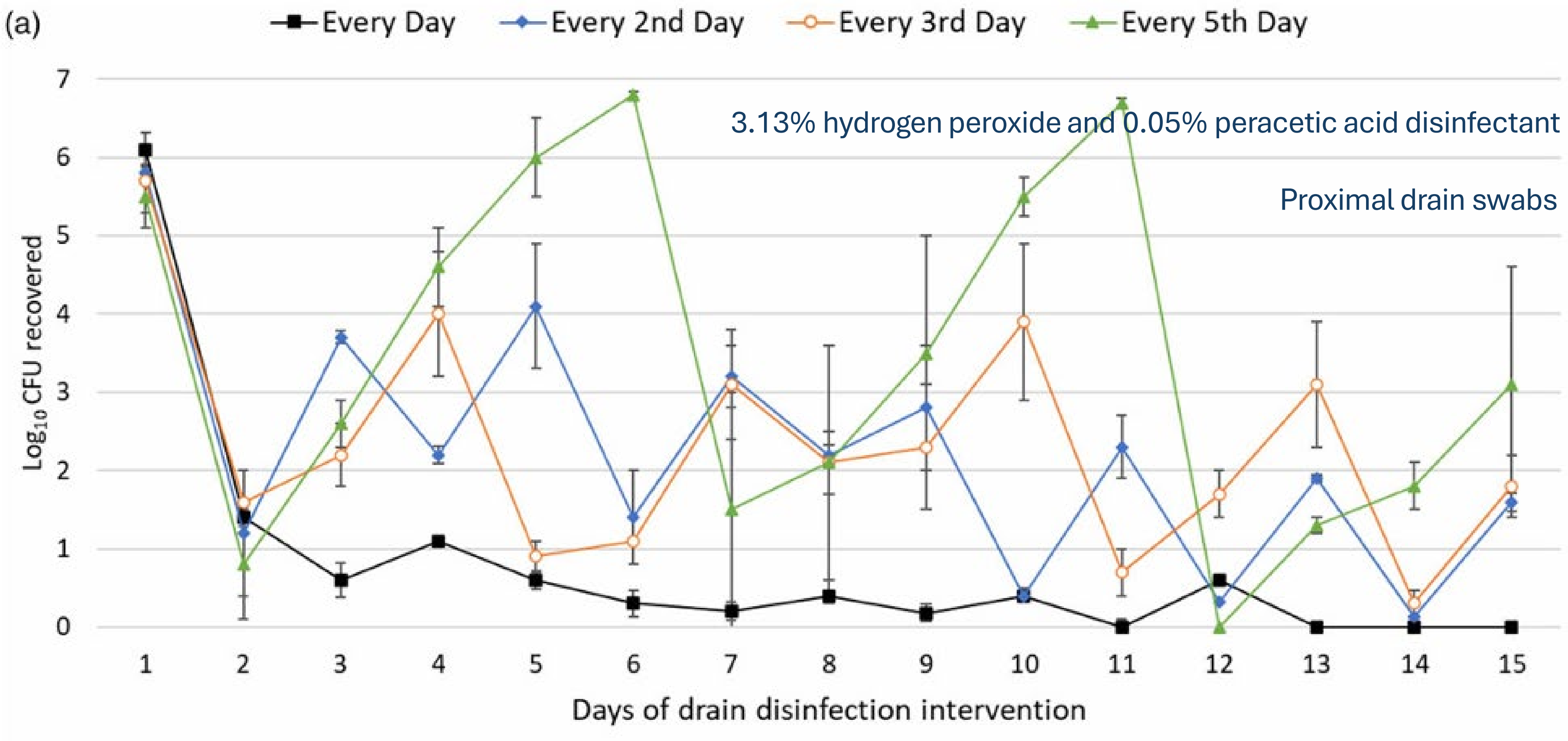



**Figure 4.** Number of sinks contaminated with Carbapenemase-producing Enterobacterales examined in 2019, 2021, and 2023. A: total numbers, B: numbers of sinks classified by the risk of contact with nutrition-rich substances; Risk L (low), Risk H (high). **: $p < .01$, ***: $p < .001$.

Varghese, et al. Infect Control Hosp Epidemiol. 2024 Sep;45(9):1143-5. PMID: 38659124

# What is the optimal frequency of sink drain decontamination with a foam disinfectant?




Chemical decontamination is a long-term commitment

# A multifaceted approach

## Human factors and hospital design

1) Address sink misuse
2) Reduce splash and opportunity for contamination of items external to the sink
   - Offset faucets
   - Adequate basin depth
   - Reduce flow and optimise drainage
   - Avoiding placing or storing items on or adjacent to a sink or toilet
   - Install physical barriers to protect surfaces and equipment
   - Reduce number of sinks in patient adjacent spaces
   - Reduce reliance on tap water where able (waterless care)

# A multifaceted approach

## Sink decontamination strategies

3) Improve sink surface integrity and remove established biofilms.

- Corrosion may lead to bacterial reservoirs which are more resistant to routine cleaning.
- Established biofilms are resistant to disinfection but return quickly after component exchange.
- Frequency needed for component exchange is unclear
- Necessary components also unclear (**faucet aerators,** sink grate, plug and waste/tailpipe, **P-trap,** sink bowl, tapware). Some more difficult than others.

4) Aim to reduce the bioburden within the sink grate, plug and waste, tailpipe, and P-trap

- Any intervention will require ongoing maintenance whether its component exchange, disinfection, or both.
- For improved decontamination, adequate contact time with all surfaces (including proximal drain components) should be sought
- Combination of the two is a reasonable approach in outbreak settings or high-risk units

# Thank you

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*Brett Mitchell*
*Josh Davis*
*John Ferguson*

*And my IPC and ICU colleagues at HNE*