Down the Drain

WATERBORNE PATHOGENS IN HEALTHCARE FACILITIES

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Disclosures

No relevant disclosures.

Objectives

- Describe the epidemiology and clinical relevance of waterborne pathogens in healthcare settings
- Discuss mechanisms of healthcare-associated transmission linked to water exposure and plumbing infrastructure
- Evaluate current and novel infection prevention strategies aimed at reducing waterborne pathogen burden

Throughout this talk, **I will share the lessons learned from an outbreak investigation in collaboration with the CDC** — a prolonged KPC-CRE outbreak traced to ICU sink drains.

THE CASE THAT GROUNDS THIS TALK

A prolonged KPC-CRE outbreak in the ICU

64
cases in 54 patients

2019–2025
Jan ’ 19 – Oct ’ 25

7
bacterial species involved

10/12
ICU sinks positive on sampling

University of Nebraska Medical Center, in collaboration with CDC, Nebraska DHHS, and Nebraska Public Health Laboratory, investigated a multi-year cluster of KPC-producing carbapenem-resistant Enterobacterales traced to ICU sink drains — with genomic evidence of horizontal plasmid transfer between species.

I will return to this case after each section to connect the evidence to what we actually found — and did — in our own units.

Source: Teran et al., Antimicrob Steward Healthc Epidemiol 2026;6(S1):s152–s153

SECTION 1

Wastewater Outbreaks: An Old Problem Hiding in Plain Sight

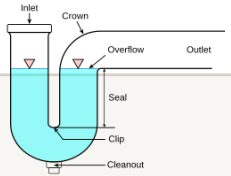
Plumbing solved one problem — and created another

Millennia of managing wastewater

- Mohenjo-daro (Indus Valley, ~2450 BCE): covered street drains, terracotta pipes, household soak pits
- Rome's Cloaca Maxima (~580 BCE): one of the first major sewer systems — sections are still in use today
- For most of history, the goal was simply moving wastewater away from people

The trap: a permanent water seal

- The S-trap was patented in 1775 by Scottish watchmaker Alexander Cumming, using standing water to block sewer gas from entering buildings
- Thomas Crapper refined it into the modern U-bend/P-trap in 1880
- London's 1858 "Great Stink" forced modern sewer construction and made trap use standard
- **That same stagnant water seal is now the ideal reservoir for biofilm**



Sources: Science Museum · Wikipedia: Trap (plumbing)

Gram-negative sink outbreaks were described 60+ years ago

- F. meningosepticum in a neonatal ward (Cabrera, USA, 1959–60)
- P. aeruginosa (as “P. pyocyanea”) linked to sinks in England (Kohn, 1963–64)
- P. aeruginosa outbreaks tied to sink drains in an operating room and multiple ICUs (Thomas 1970; Teres 1970–72; Edmonds 1971)
- K. aerogenes recovered repeatedly from sinks in England through the late 1970s (Riser 1971–76)

> *“The first suggestions to heat sink traps or modify sink construction to reduce splashing were made more than 40 years ago.”*

Source: Volling et al., Open Forum Infect Dis 2021;8(2):ofaa590

Healthcare-associated infections are declining — but not all of them

2.6%
of patients had ≥1 HAI in the 2023 NHSN prevalence survey, down from 3.2% in 2015 (a 27% relative decrease)

66.9%
of HAIs had a pathogen identified (357 pathogens across 261 HAIs)

51%
of identified HAIs were caused by S. aureus (46% MRSA), E. coli, or C. difficile

- Pneumonia, surgical site infections, and gastrointestinal infections were the most common HAI types
- Water-associated organisms remain a meaningful minority: Pseudomonas aeruginosa 7%, Klebsiella spp. 6%, Enterobacter spp. 3%, Serratia spp. 2%

Source: N Engl J Med. 2026 Jul 16;395(3):255-266

These organisms rank high on national AMR surveillance

- CDC NHSN 2018–2021 antimicrobial-resistance report: Pseudomonas aeruginosa was the 5th most common pathogen overall (36,004 isolates) and the 2nd most common cause of ventilator-associated pneumonia
- Serratia spp. and Stenotrophomonas spp. ranked 6th and 7th for pneumonia in ventilated patients
- **Citrobacter spp. ranked 12th overall — the same genus that later dominated our own outbreak isolates**

These are not exotic organisms — they are already among the most common drivers of resistant healthcare-associated infection in the US.

Source: CDC NHSN AMR Report, Tables 3 & 6

One in five outbreak consults involved water — excluding Legionella

21.6%
134 of 620 CDC consultations (2014–2017) met criteria for a water-related outbreak, excluding Legionella

1,380
patients affected across those investigations — an average of 10.3 per investigation

33.6%
of investigations involved a multidrug-resistant organism

- Nontuberculous mycobacteria caused the most investigations (29.9%) and affected the most patients (39.8%)
- Medical products and devices drove >35% of investigations — heater-cooler units, bronchoscopes, and other endoscopes were the leading device categories

Source: Infect Control Hosp Epidemiol. 2019 Jun;40(6):621-626

Regulators took notice

Since June 2017, the Centers for Medicare & Medicaid Services (CMS) has required hospitals, critical access hospitals, and long-term care facilities to establish and maintain water management programs aimed at preventing the growth and spread of *Legionella*. Under CMS memorandum S&C 17-30, facilities must implement water management policies and procedures that incorporate the principles outlined in ASHRAE Standard 188 and the CDC toolkit for managing *Legionella* risks in building water systems.

This is exactly the kind of problem that hides in plain sight

- Our outbreak spanned January 2019 through October 2025 — nearly 7 years — before it was fully characterized
- 64 cases in 54 patients, involving 7 different bacterial genera, all traced back to the same reservoir: ICU and step-down unit sink drains
- Like the outbreaks described over the last 60+ years, ours was hiding in ordinary plumbing that every unit already had

↩ BACK TO THE CASE

Environmental sampling in May 2025 found KPC-CRE in 10 of 12 ICU sinks, 2 of 12 ICU hoppers, and 1 of 22 step-down-unit sinks — confirming the drains as the shared reservoir.

Source: Teran et al., Antimicrob Steward Healthc Epidemiol 2026

SECTION 2

Design matters

Drain covers cut splash contamination dramatically

- 109 of 112 sink drains (97%) across 7 hospital wards grew gram-negative bacilli, including Pseudomonas
- 8 of 10 sinks (80%) with contaminated gowns or hands matched the predominant organism in that sink's drain
- A simple plastic drain cover reduced contamination during handwashing: countertop 11% → 1%, gowns 9% → 2%, hands 6% → 0% (P≤.03)

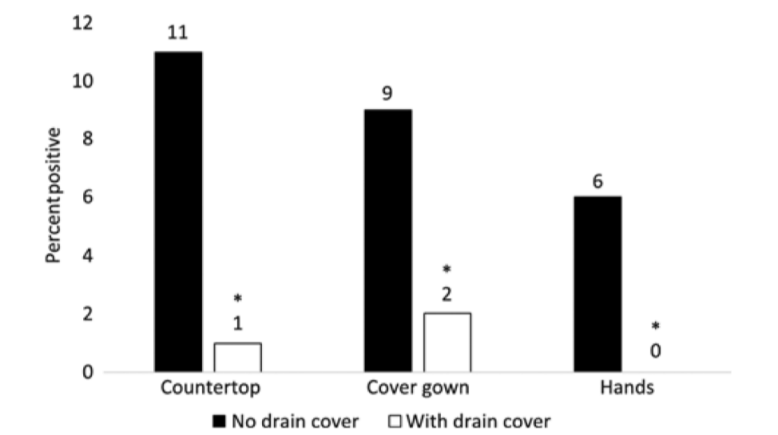


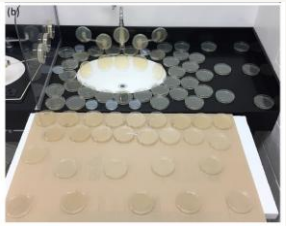
Fig. 2. Percentage of sink countertops, cover gowns, and hands with positive cultures for gram-negative bacilli after washing hands for 15 seconds with versus without a plastic sink drain cap in place. *, $P \leq .03$.

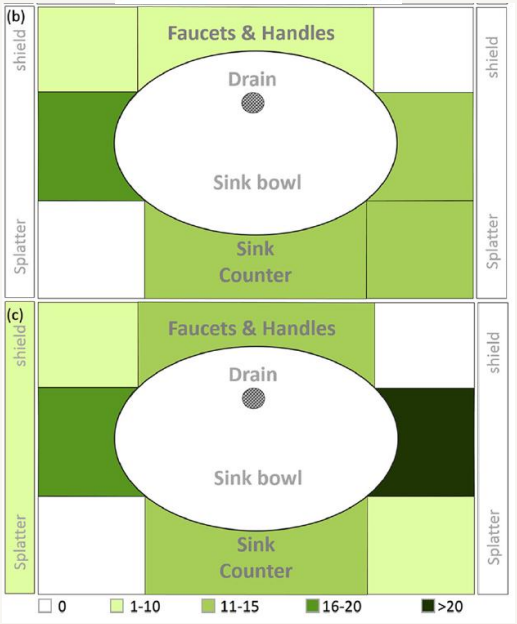
Contamination with vs. without a drain cover

Source: Infect Control Hosp Epidemiol. 2019 Apr;40(4):460-462

Splash from a colonized drain travels well beyond the bowl

- A fluorescent-marker experiment showed splash dispersion is far greater when the drain is pre-colonized with bacteria
- Droplets reached the faucet, handles, and sink counter; Zones that patient supplies and staff hands routinely contact
- Splash risk is highest directly around the drain and diminishes, but does not disappear, moving outward

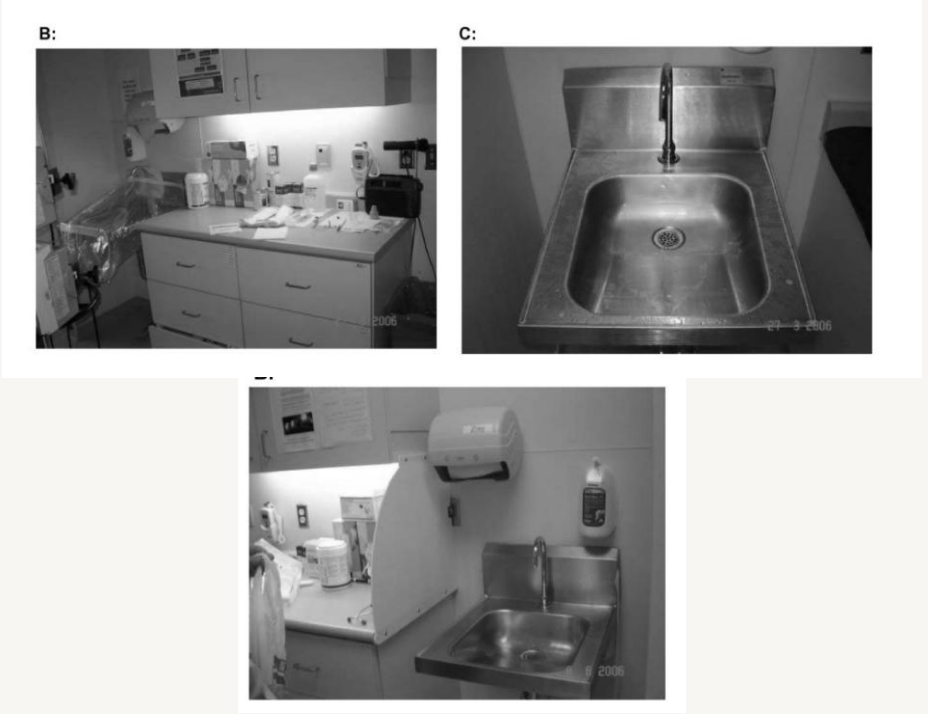




Source: Kotay et al., Appl Environ Microbiol. 2017;83(8):e03327-16

Toronto General Hospital: an outbreak terminated only by redesign

- 36 patients affected by MDR Pseudomonas aeruginosa in ICU and transplant units, Dec 2004 – Mar 2006
- A fluorescent tracer showed splash from the hand-hygiene sink drain traveled ≥ 1 meter onto nearby surfaces and supplies
- **The outbreak ended only after the sinks were physically renovated to prevent splashing — disinfection alone had not worked**



Source: Infect Control Hosp Epidemiol. 2009 Jan;30(1):25-33

Design and habit created our splash zone problem too

- IPC rounding in our units found patient-care items sitting directly in the sink splash zone
- **Most notably: “bath-in-a-bag” patient bathing wipes were being placed in the sink itself, and graduated cylinders and syringes for free water flushes**
- That single practice put a splash-exposed, reusable-adjacent item in direct contact with the same drains found to harbor KPC-CRE

↩ BACK TO THE CASE

In May 2025 we launched a campaign to remove all patient-care items from the sink splash zone — including stopping the practice of placing bath-in-a-bag supplies in the sink and switching to chg wipes.

Source: Teran et al., Antimicrob Steward Healthc Epidemiol 2026

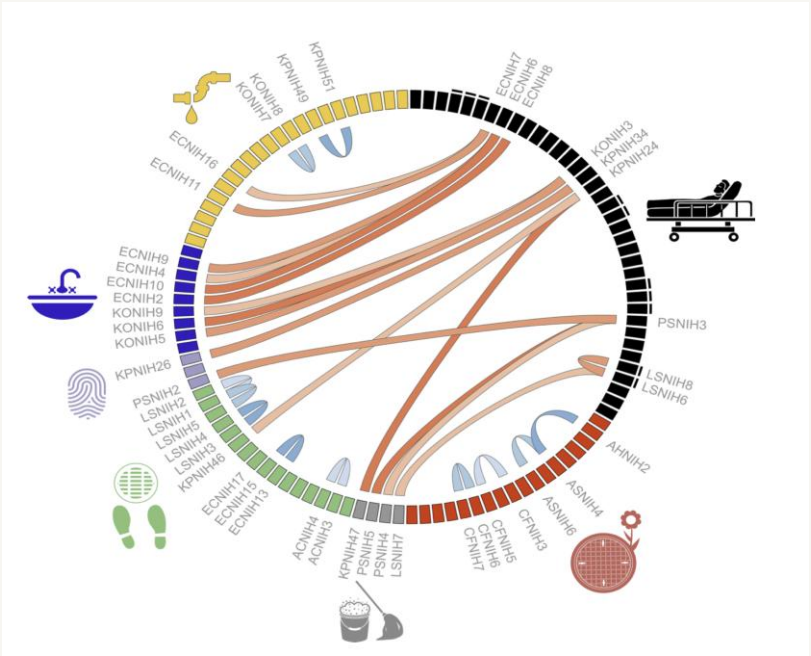
SECTION 3

The biofilm's Sobremesa: better together, but Please, No Soda

Pouring nutrients and antibiotics down the drain promotes biofilm and bacterial growth.

Wastewater piping, not surfaces, was the reservoir at the NIH Clinical Center

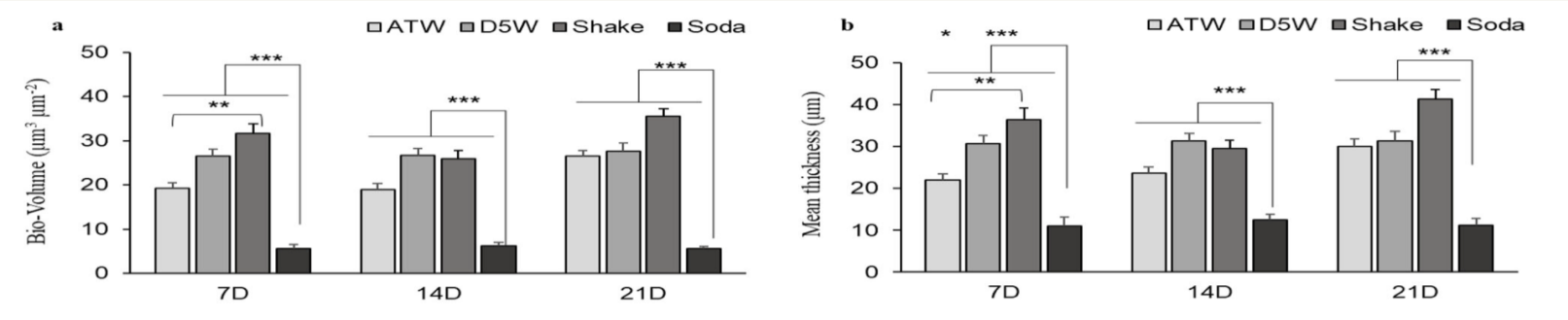
- 19 patients affected by blaKPC-positive Klebsiella pneumoniae in a 2011 outbreak
- Only 3 of 217 high-touch surface samples (1.4%) were positive over 5 years of sampling
- **By contrast, 7 of 7 ICU wastewater piping samples (100%) and all manhole samples were positive**
- Genomic analysis (circos plot) showed close relatedness between drain and patient isolates, with some species — Serratia spp., E. coli — recovered only from the environment



Source: mBio. 2018 Feb 6;9(1):e02011-17

What goes down the drain feeds what lives in it

- An in-vitro biofilm reactor tested 6 native P-trap organisms plus 2 blaKPC-positive K. pneumoniae strains, fed daily with dextrose water (D5W), Ensure shake, Coca-Cola, or plain tap water for 28 days
- **D5W and Ensure shake increased bacterial counts and biofilm thickness — a clear nutritional effect**
- Soda-fed coupons had high dead-cell counts, but viable-but-nonculturable (VBNC) organisms were still detected by live/dead staining even with no culturable colonies



Source: Biofouling. 2021 May;37(5):465-480

Nutrients poured down our drains were feeding the biofilm

- Like the NIH outbreak, our organisms were genetically related across the drain-to-patient pathway, spanning multiple genera
- Clinical practice in our ICU/step-down unit included pouring lipids and total parenteral nutrition (TPN) down sink drains — exactly the nutrient sources shown experimentally to accelerate biofilm growth

↩ BACK TO THE CASE

Starting in July 2025, we stopped disposal of lipids and TPN down sink drains as part of the remediation bundle — directly targeting the nutrient supply sustaining the biofilm reservoir.

Source: Teran et al., Antimicrob Steward Healthc Epidemiol 2026

SECTION 4

What doesn’t kill you make you stronger

Two tracks of response: infection control and engineering

Approaches if known patient infection/colonization with sink-related pathogen*

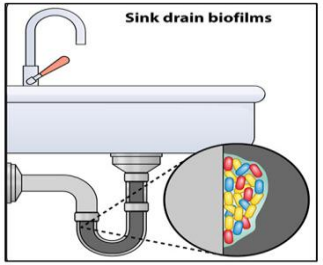
Infection Prevention and Control Strategies (Sink-related) [a]
- Mechanical removal of biofilm [b]
- Enhanced cleaning/disinfection of surfaces in or near sink
- Keeping supplies and patient care items far from drains
- Dedicated handwashing sinks
- Waste disposal and liquid nutrient sink discharge policies and education of staff/visitors.

Chemical approaches if known patient infection/colonization with sink-related pathogen

Most effective

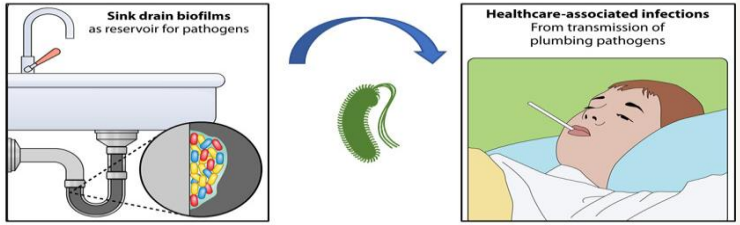
Engineering Controls, Infection Prevention Control Practices, Sink Decontamination [d, e]
- Foaming peracetic acid/hydrogen peroxide with descaling agent
- Foaming peracetic acid/hydrogen peroxide
- Foaming peracetic acid
- Hydrogen Peroxide
- Peracetic acid
- Acetic acid
- Sodium dichloroisocyanurate
- Sodium hypochlorite
- Quaternary ammonium compounds

Least effective



Approaches if known sink colonization with pathogen*

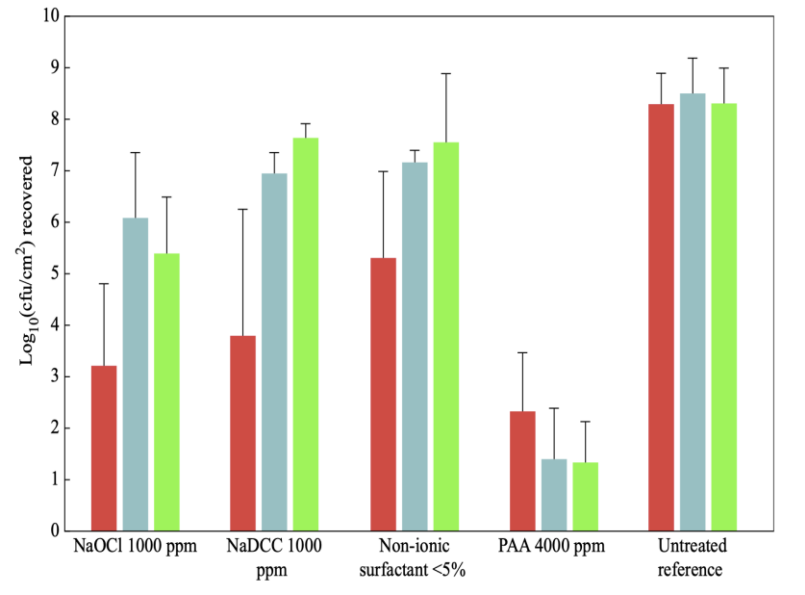
Engineering Controls [c]
- Mechanical removal of biofilm [b]
- Installation of barriers to prevent splashes from reaching nearby surfaces
- Reduction of splashing and aerosols (reduce water pressure, offset drains, drain covers, etc.)
- Investigation/remediation of slow-draining sinks
- Implementation of waterless patient care
- Incorporation of wastewater premise plumbing into water management plans



Source: Clin Microbiol Rev. 2025;38(4):e0006124

Peracetic acid consistently outperforms other disinfectants in vitro

- FDA regulates disinfectants used on critical/semicritical devices; EPA regulates environmental surface disinfectants
- A peracetic-acid-based product was the first to receive EPA registration specifically for biofilm treatment, in 2020
- Across 119 species recovered from trap tubing, peracetic acid (PAA, 4000ppm) left far less recoverable bioburden than sodium hypochlorite, NaDCC, or surfactant — with no significant difference by trap location (P=0.83)



Log10 CFU/cm² recovered after 3 disinfectant doses

Sources: CDC: Regulatory Framework for Disinfectants · J Hosp Infect. 2020 Dec;106(4):757-764

Peracetic acid works — but regrowth is fast without repeated dosing

Brussels, >700-bed - ICU

- 23 of 40 sink drains (57.5%) carried carbapenem-resistant organisms, including VIM-producing P. aeruginosa
- **A 4-week PAA decontamination protocol cleared P-trap water cultures immediately — but regrowth exceeded 100,000 CFU/mL within 72 hours, before the next disinfection cycle**

Idaho hospital ICU

- Carbapenemase-producing P. aeruginosa recovered from 2 patients and a matching sink in the same room, 4 months apart
- A foaming peracetic-acid biofilm disinfectant applied repeatedly cleared the organism — no further isolates through the following year

Source: Hosp Infect. 2024 Dec;154:45-52

Acetic acid: a pragmatic bridge while sinks await replacement

- An 800-bed Swedish hospital identified 14 patients with VIM-producing P. aeruginosa (2 fatal) traced to 12 sink drains in patient bathrooms
- Where sinks could not be replaced immediately, weekly 250mL 24% acetic acid (30-minute contact) was used as an interim measure
- After full sink/plumbing replacement, the organism reappeared in 3 sinks after a mean of 13 weeks; 2 drainpipes remained positive after 10 weeks of acetic acid and needed high-pressure 90°C flushing

> *“Installation of sinks constructed to prevent bacterial transmission would be our preferred response, but in a suboptimal setting acetic acid is proposed as a simple and inexpensive method.”*

Source: J Hosp Infect. 2016;94(1):13-20

Routine disinfectant use still leaves a quarter of sinks positive

Sheba Medical Center, Israel

- 1,600-bed center; routine cleaning included pouring 500mL of 1000ppm NaDCC down room sinks daily
- **592 patient-room sinks tested — 144 (24%) remained contaminated with carbapenemase-producing organisms across 25 of 34 departments**
- Of the 9 departments without contamination, 7 had been newly renovated

Toronto General (revisited)

- Post-intervention hydrogen-peroxide-gel disinfection produced sterile cultures — but hand-hygiene sinks recolonized over time
- **Disinfection alone had no lasting impact on eradicating the outbreak strain; only structural redesign ultimately worked**

Sources: Regev-Yochay et al., Infect Control Hosp Epidemiol. 2023 · Infect Control Hosp Epidemiol. 2009 Jan;30(1):25-33

Disinfection bought us time — it did not solve the problem

- In May 2025 we began daily use of an EPA-registered, NaDCC-based biofilm drain disinfectant
- **On repeat environmental sampling in June 2025, KPC-CRE was still detected in sink drains despite this disinfection regimen**

↩ BACK TO THE CASE

This mirrors every case in this section: disinfectants are a temporary measure. Recolonization is common, and disinfection alone was not sufficient to interrupt transmission in our units — it had to be paired with the splash-zone and nutrient changes already discussed.

Source: Teran et al., Antimicrob Steward Healthc Epidemiol 2026

SECTION 5

Throw Out the Kitchen Sink - And the ICU Sink While You're at It

Replacing faucets bought weeks, not clearance

- NIH Clinical Center, 2016: 6 inpatients with Sphingomonas over 6 months; 12 total cases traced back to 2006 (a year after the hospital opened)
- S. koreensis grew from 22 of 56 faucets (39%) and 9 of 17 water samples (53%), genetically related to the clinical isolates
- A decade of near-identical isolates (11–41 chromosomal SNVs) showed the organism can persist in low-nutrient stasis for years
- **9 positive faucets were replaced — 6 of 9 new faucets (67%) were recolonized within just 5 to 90 days**

Source: N Engl J Med. 2018 Dec 27;379(26):2529-2539

A Swiss ICU eliminated new acquisitions by going “waterfree”

- March 2018 – Sept 2020: 21 patients newly colonized or infected with VIM-53 P. aeruginosa; 76.2% had ICU-linked acquisition
- Of 131 environmental samples, 16 (12.2%) were positive — mostly sink traps and strainers; all sequenced isolates were the same strain type (ST-111)
- In Sept 2020, after 3 more acquisitions, the ICU removed sinks from patient rooms and most medication-prep areas
- **No new acquisitions occurred over the next 8 months**

Source: Crit Care. 2021;25(1):301

Removing sinks measurably reduced colonization in the Netherlands

- Early 2014: ESBL-producing Enterobacter cloacae outbreak prompted a 953-bed hospital- ICU to remove sinks and adopt “water-free” patient care
- Gram-negative colonization fell from 26.3 to 21.6 per 1,000 admission-days (RR 0.82, P=0.02); yeasts, the negative control, did not change
- **For cultures ≥5 days into admission, the reduction was even larger: 15.0 → 9.4 per 1,000 admission-days (RR 0.63)**

Table 1 ‘Water-free’ patient care activities

Patient care-related action	New method with ‘water-free’ working
Gloves and gowns	Universal gloving and gowning (pre- and post-intervention period)
Hand washing after visual contamination	‘Quick & Clean’, (Alpheios B.V., Heerlen, The Netherlands) wipes to remove extensive contamination from hands. Followed by disinfection with alcohol-based hand rub
Medication preparation	Dissolving of medication in bottled water (SPA reine, Spa, Belgium)
Drinks	Bottled water (SPA reine, Spa, Belgium)
Canula care	Disposable materials
Hair washing	Rinse-free shampoo cap (Comfort Personal cleansing products, USA)
Washing	Moistened disposable wash gloves, (D-care,Houten, The Netherlands)
Dental care	Bottled (SPA reine, Spa, Belgium)
Shaving	Electric shaving, or with warm bottled water (SPA reine, Spa, Belgium)

Source: Antimicrob Resist Infect Control. 2017 Jun 10;6:59

We did not remove the sinks — and it still worked

- Full sink removal is effective but can be expensive and not always feasible on short notice in an active outbreak
- Our remediation combined behavioral and sink hygiene measures instead: splash-zone item removal, CHG wipes, and stopping nutrient disposal down drains. Unclear benefit from biofilm disinfectant.

↩ **BACK TO THE CASE**

No additional cases were identified in the ICU or step-down unit after these remediation activities — removing patient items from the sink splash zone was a pragmatic, low-cost intervention that mattered as much as any chemical measure.

Source: Teran et al., Antimicrob Steward Healthc Epidemiol 2026

SECTION 6

See no evil, speak no evil, hear no evil

If you don’t look for them, you won’t find them — whole genome sequencing and its role in investigation

Routine surveillance is not built to catch this

- Standard clinical cultures target infection, not environmental colonization — a quiet drain reservoir generates no alert on its own
- Cases often accumulate slowly across years and multiple units before anyone connects them
- **Finding these outbreaks requires high clinical suspicion, deliberate lookback at microbiology data, and increasingly, genomic sequencing to prove relatedness across strains and species**

Our case: how it was found, and how big it was

- **A rise in blaKPC-4 — a carbapenemase variant uncommon in the US — prompted a retrospective review of cases, which revealed clustering around the ICU and step-down unit**
- 64 cases in 54 patients (37 clinical, 27 screening) identified from January 2019 through October 2025; 28 patients had an ICU/SDU admission during their hospitalization
- Clinical cases detected by Xpert Carba-R PCR and multiplex panels; screening used PCR with reflex to culture
- 7 bacterial genera involved — Citrobacter (26 cases), Klebsiella (14), Raoultella (5), and others

Source: Teran et al., Antimicrob Steward Healthc Epidemiol 2026

Whole-genome sequencing revealed the real story: plasmid transfer

- 17 isolates spanning 5 different bacterial species carried blaKPC-2 on the same 42kb IncP6 plasmid
- 10 isolates spanning 5 species carried blaKPC-4 on a shared 69kb plasmid (Col440I + IncM1 replicons)
- **Environmental isolates from the sink drains were genetically closely related to clinical isolates and carried the identical plasmids**
- This is direct genomic evidence of horizontal plasmid transfer across bacterial genera through a shared drain reservoir — something routine species-level identification alone could never reveal


KPC-4 Is Encoded within a Truncated Tn*4401* in an IncL/M Plasmid, pNE1280, Isolated from *Enterobacter cloacae* and *Serratia marcescens*

Authors: Kendall A. Bryant, Trevor C. Van Schooneveld, Ishwor Thapa, Dhundy Bastola, Laurina O. Williams, Thomas J. Safranek, Steven H. Hinrichs, Mark E. Rupp, Paul D. Fey | AUTHORS INFO & AFFILIATIONS

Source: Teran et al., Antimicrob Steward Healthc Epidemiol 2026

The remediation timeline — and the result

May 2025	Removed items from the sink splash zone (incl. bath-in-a-bag and water flushes supplies); switched to CHG wipes; began daily NaDCC-based drain biofilm disinfectant
Jun 2025	Repeat environmental sampling — KPC-CRE still detected in sink drains despite disinfection
Jul 2025+	Stopped disposal of lipids and TPN down sink drains
Outcome	No additional cases identified in the ICU or step-down unit after these combined interventions

Source: Teran et al., Antimicrob Steward Healthc Epidemiol 2026

Others found their outbreaks the same way: by looking back

Sweden, VIM-P. aeruginosa

- Only identified after 2 deaths prompted a lookback through years of microbiology data — revealing 12 additional cases that had gone unrecognized

NIH, Sphingomonas

- Required a decade-long lookback and high clinical suspicion to connect 2016 cases to isolates from 2006, a year after the hospital opened

Sources: J Hosp Infect. 2016;94(1):13-20 · N Engl J Med. 2018 Dec 27;379(26):2529-2539

A proactive sink surveillance program can show what's working

- A Japanese children's hospital cultured 180 sinks across 9 wards, including a pediatric ICU, in 3 rounds: 2019, 2021, and 2023
- CPE-positive sinks fell steadily after daily sodium-hypochlorite disinfection was introduced: 30 sinks (16.7%) in 2019 → 13 (7.2%) in 2021 → 6 (3.3%) in 2023
- Molecular typing showed patient isolates matched isolates from sinks on their own ward — confirming ongoing transmission risk even as overall positivity declined
- **Sinks used to discard nutrient-rich substances (milk, parenteral fluids) showed no significant decline despite disinfection**

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

LESSONS LEARNED FROM OUR OUTBREAK

Six lessons, one reservoir

1

Old problem

Sink-drain outbreaks have been documented for 60+ years — this is a known, recurring risk, not a novel one

2

Design matters

Splash zones extend ≥ 1m from the drain; keep patient items and supplies out of them

3

Feed nothing

Lipids, TPN, and other nutrients poured down drains directly fuel biofilm growth

4

Disinfect, but don’t stop there

Chemical disinfection is temporary; recolonization is common even with rigorous protocols

5

Engineering helps, doesn’t cure

Sink/faucet removal reduces risk but does not guarantee elimination — behavior change still matters

6

Look for it

Routine surveillance misses this; WGS and proactive drain culturing reveal transmission that culture alone cannot

Conclusion

- Wastewater plumbing and sink drains are a well-documented, recurring reservoir for healthcare-associated multidrug-resistant organisms
- Splash-zone design, nutrient disposal, and disinfectant selection all shape whether that reservoir reaches patients
- No single intervention — chemical or engineering — reliably eliminates a colonized drain on its own; durable control requires a bundle of measures
- **Our own KPC-CRE outbreak resolved only once we combined splash-zone practice change, disinfection, and nutrient-source removal — identified in the first place through genomic sequencing and high clinical suspicion**

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Questions & discussion

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