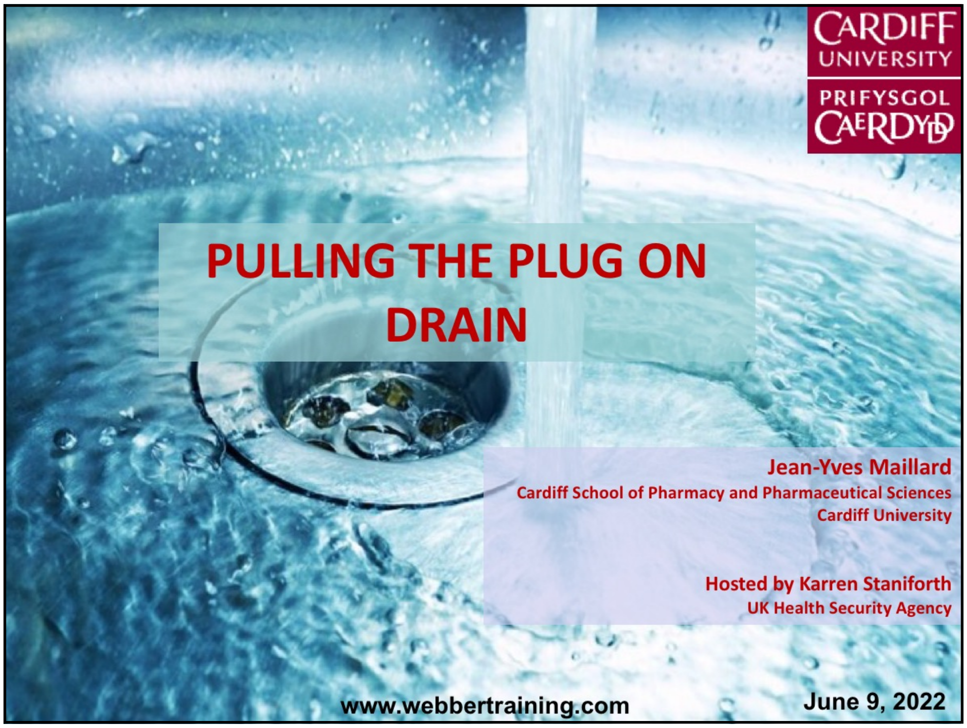

Objectives

- Sink drain and hospital acquired infection
- Sink usage in healthcare settings
- Microbial biofilms and resilience to disinfection
- Microbial biofilms and antimicrobial resistance
- Impact of drain disinfectants on complex biofilms

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Sink, drain and infection

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- Sinks and drains support long-term persistence of MDRO (Enterobacteriaceae) and *Pseudomonas aeruginosa*
- Clear epidemiological links between sinks and drains and MDRO (CRE) colonization/infection of patients
- Clear epidemiological links between sinks and drains and persistent reservoir between patient associated outbreak

3

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Sink, drain and infection

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NEED

- Hand hygiene is a vital IPC practice
- Long campaign to promote hand hygiene led to increased installation of handwashing sinks

ISSUES

- Aerosols and splash water have been detected up to one metre away from sinks
- Gram negative bacteria found in aerosols produced by running water in up to 93% of sink

RISK

- Contamination of the critical care environment via handwashing sinks has been linked to patient infections
- Sub-optimal room and sink designs put patients/staff at risk.

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Sink, drain and infection

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American Journal of Infection Control 42 (2014) 554-5
Contents lists available at ScienceDirect
American Journal of Infection Control
journal homepage: www.ajicjournal.org

Brief report

The important role of sink location in handwashing compliance and microbial sink contamination

Elaine Cloutman-Green MRes, MSc[a,*], Oya Kalaycioglu MSc[b], Hedieh Wojani BArch[c,d], John C. Hartley BSc, MBBS, DTM&H, MSc[a], Serge Guillas PhD[b], Deirdre Malone BSc[a], Vanya Gant PhD[e], Colin Grey MPhil, MCIOB[d], Nigel Klein PhD[c]

- Number of handwashing episodes increased with increased sink visibility
- Increased usage positively correlated with increased contamination within the bowl of the sink.
- Contamination of sink lips and soap/alcohol dispensers inversely related to sink usage

- Enterobacteriaceae detected at all sites except for soap and alcohol dispenser
- Staphylococcal species were detected at all sites.

5

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Sink usage

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Infection Control & Hospital Epidemiology (2018), **39**, 1463–1466
doi:10.1017/ice.2018.273

Commentary

Water as a source for colonization and infection with multidrug-resistant pathogens: Focus on sinks

Sarah S. Lewis MD, MPH[1,2], Becky A. Smith[1,2], Emily E. Sickbert-Bennett[3,4] and David J. Weber[3,4]
[1]Infection Prevention and Hospital Epidemiology, Duke University Hospital, Durham, North Carolina, [2]Division of Infectious Diseases, Duke University School of Medicine, Durham, North Carolina, [3]Department of Hospital Epidemiology, University of North Carolina Hospitals, Chapel Hill, North Carolina and [4]Division of Infectious Diseases, University of North Carolina School of Medicine, Chapel Hill, North Carolina

(Received 19 September 2018; accepted 30 September 2018)

- Hand washing by healthcare personnel, patients, and visitors.
- Disposal of body fluids (e.g. dialysate, urine, gastric residuals) or unused medications or tube feeds
- Commonly used during perineal care (both routine care and after bowel movements) and for patient bathing
- Soaking and initial cleaning of equipment that will undergo sterilization or high-level disinfection.

6

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Sink usage

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

Infection Control & Hospital Epidemiology (2018), **39**, 1463–1466
doi:10.1017/ice.2018.273

SHEA

Commentary

Water as a source for colonization and infection with multidrug-resistant pathogens: Focus on sinks

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(Received 19 September 2018; accepted 30 September 2018)

Infection prevention principles dictate separation of clean and dirty areas and tasks.

- Clinical sinks are not present in all acute-care hospital rooms
- Common practice for clean and dirty activities, including hand hygiene and waste disposal, to occur in the same in-room sink.
- High-risk situation: enhance biofilm formation + sink proximity to patient care equipment and room surfaces

Sink, drain and infection

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de Abreu *et al. BMC Microbiology* 2014, **14**:118
http://www.biomedcentral.com/1471-2180/14/118

BMC Microbiology

RESEARCH ARTICLE Open Access

Persistence of microbial communities including *Pseudomonas aeruginosa* in a hospital environment: a potential health hazard

Pedro Miguel de Abreu[1], Pedro Geadas Farias[1], Gabriel Silva Paiva[2], Ana Maria Almeida[1] and Paula Vasconcelos Morais[2,3*]

"The environment may act as a reservoir for at least some of the pathogens implicated in nosocomial infections."

- 290 environmental samples analysed over 2 years
- *P. aeruginosa* was repeatedly isolated from:
  - sinks (10 times)
  - the taps' biofilm (16 times)
  - showers and bedside tables (two times).
- Contamination level of the different taps correlated with contamination level of the hand gels support, soaps and sinks.

Sink, drain and infection

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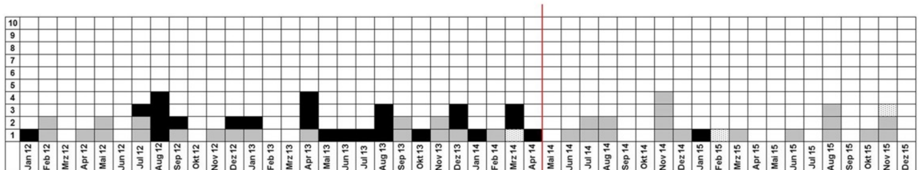
Salm et al. Antimicrobial Resistance and Infection Control (2016) 5:53
DOI 10.1186/s13756-016-0157-9
Antimicrobial Resistance and Infection Control
RESEARCH Open Access

Prolonged outbreak of clonal MDR *Pseudomonas aeruginosa* on an intensive care unit: contaminated sinks and contamination of ultra-filtrate bags as possible route of transmission?

Florian Salm[1*], Maria Deja[2], Petra Gastmeier[1], Axel Kola[1], Sonja Hansen[1], Michael Behnke[1], Désirée Gruhl[1] and Rasmus Leistner[1]

- *P. aeruginosa* outbreak strain found in 5/16 sinks patient rooms
- Stay in a room with a colonized sink (Odds Ratio[OR] 11.2, p = 0.007) and hemofiltration (OR 21.9, p = 0.020) independently associated with elevated risk for colonization or infection
- Ultra-filtrate bags emptied in sinks on average five times per day



Outbreak clone (MDR *P. aeruginosa*)
MDR *P. aeruginosa* different from outbreak clone
Isolate not retrievable for geno-typing

Change traps
Eliminated work procedures involving sinks
in Implementation of single use bags

Sink, drain and infection

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Contents lists available at ScienceDirect
Clinical Microbiology and Infection
journal homepage: www.clinicalmicrobiologyandinfection.com
Original article

A prospective multicentre surveillance study to investigate the risk associated with contaminated sinks in the intensive care unit

Anne-Sophie Valentin[1], Sandra Dos Santos[1], Florent Goube[1], Rémi Gimenes[1], Marie Decalonne[1], Laurent Mereghetti[2], Côme Daniau[3], Nathalie van der Mee-Marquet[1,2] on behalf of the SPIADI ICU group

- 73 ICUs
- 606/1191 (50.9%) sinks contaminated by MDR bacteria
- 41.0% used only for handwashing
- 55.3% used for waste disposal
- 38.5% showed visible splashes
- 30.5% close to the bed (<2 m) with no barrier around the sink

Contamination rates

MDR-associated bloodstream infection incidence rates 0.70/1000 patient days associated with 3-4 of the following:

- sink contamination rate
- prevalence of sinks with visible splashes
- prevalence of sinks close to the patient's bed
- No daily bleach disinfection

Sink, drain and infection

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[1] Mission Nationale SPIADI, Centre d'Appui pour la Prévention des Infections Associées aux Soins en Région Centre Val de Loire, Centre Hospitalier Universitaire, Tours, France
[2] Service de Bactériologie, Virologie et Hygiène, Centre Hospitalier Universitaire, Tours, France
[3] Unité Infections Associées aux Soins et Résistance aux Antibiotiques, Agence Santé Publique France, Saint Maurice, France

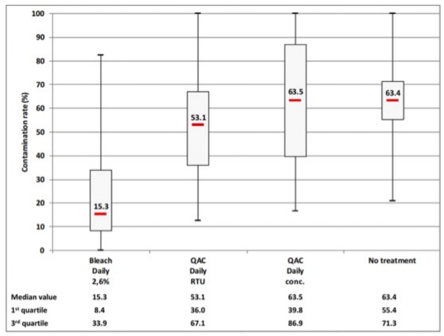

Fig. 1. Box plots representative of the sink contamination rates observed in the 73 ICUs, according to the daily sink treatment (2.6% bleach solution, ready-to-use [illegible] (concentrated quaternary ammonium compound) QAC solution) and for sinks with no routine disinfection.

- 38.4% reported lack of sink disinfection
- When sink disinfection was implemented, 68.9% disinfection mostly performed daily using bleach (57.8%) or QAC (42.2%)

DISINFECTION

Sink, drain and infection

Journal of Hospital Infection 85 (2013) 106–111
Available online at www.sciencedirect.com
Journal of Hospital Infection
journal homepage: www.elsevierhealth.com/journals/jhin

Contaminated sinks in intensive care units: an underestimated source of extended-spectrum beta-lactamase-producing Enterobacteriaceae in the patient environment

D. Roux [a], B. Aubier [a], H. Cochard [a], R. Quentin [b], N. van der Mee-Marquet [a,b,*], for the HAI Prevention Group of the Réseau des Hygiénistes du Centre

- 57 sinks (31%) contaminated with ESBLE (*Klebsiella* and *Enterobacter*)
- 81 sinks (44%) were used for handwashing as well as the disposal of body fluids

Table IV
Risk factors for contamination of sinks and clinical areas near to the sink for extended-spectrum beta-lactamase-producing Enterobacteriaceae (ESBLE)-contaminated and ESBLE-free sinks

Risk factors	Sinks			
	All	ESBLE-contaminated ($N = 57$)	ESBLE-free ($N = 128$)	P
Sink use				
Handwashing only	51	7	44	$P < 0.001$
Patient toilet	84	50	34	
Splash risk factor	67	23	44	
Aerator	34	9	25	
Water directed straight into the drain	103	39	64	
Visible splash when tap turned on	34	17	17	
Distance between the sink and patient bed				
<1 m	2	1	1	
1–2 m	56	22	34	
Splash barrier	12	1	11	
Routine sink disinfection	158	54	104	
Daily	116	37	79	
Weekly	20	9	11	
Bleach	39	9	30	
Daily	19	0	19	$P < 0.001$
Weekly	20	9	11	
Quaternary ammonium compounds daily	56	20	36	

Sink, drain and infection

Journal of Hospital Infection 85 (2013) 106–111
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D. Roux[a], B. Aubier[a], H. Cochard[a], R. Quentin[b], N. van der Mee-Marquet[a,b,*], for the HAI Prevention Group of the Réseau des Hygiénistes du Centre

- Splash risk identified for 67 sinks (36%) - 23 contaminated by ESBLE.
- Routine sink disinfection frequent (85%), mostly daily (75%), QAC (41%) or bleach (21%)
- Lower sink contamination rate significantly associated with sink restricted to handwashing only and daily sink disinfection using bleach

Table IV
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Sink, drain and infection

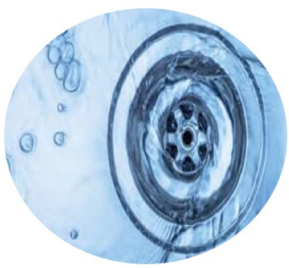
Journal of Critical Care 66 (2021) 52–59
Contents lists available at ScienceDirect
Journal of Critical Care
journal homepage: www.journals.elsevier.com/journal-of-critical-care

Preventing infections caused by carbapenemase-producing bacteria in the intensive care unit - Think about the sink

A. Kearney[a,*], M.A. Boyle[a], G.F. Curley[b], H. Humphreys[a,c]
[a] Department of Clinical Microbiology, the Royal College of Surgeons in Ireland, Ireland
[b] Department of Anaesthesia and Critical Care, the Royal College of Surgeons in Ireland, Ireland
[c] Department of Microbiology, Beaumont Hospital, Dublin, Ireland

Intervention studies targeting elements of sinks used in response to outbreaks in critical care units (n=30).

- Sink removal
- Use of physical barriers or design modification to protect patients from sinks
- Engineering controls to mitigate bacterial dispersal
- Administrative controls



Sink, drain and infection

SINK REMOVAL

- Remove handwashing sinks from critical care units.
  - Implementation of wipes + alcohol hand gel
  - In the long term as new washbasins and pipework rapidly become recolonized

BARRIER

- Physical barriers or room modification to protect patients from sinks.
  - Splash screen
  - Sink away from patients (area around sink still prone to contamination)

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Sink, drain and infection

ENGINEERING

- Engineering controls: Physical design modifications to prevent or minimise dispersal of bacteria
  - Novel drain covers
  - Waste disposal and use of heating and vibration units, to remove drain contamination
  - Automated trap disinfection devices
  - Novel sink design (reducing splashes)
  - Self-disinfecting siphons

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Sink, drain and infection

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CONTROL

- Disinfection
  - Bleach / PAA *vs.* QAC
  - Frequency (daily/ weekly)
  - Compliance
  - Temporary solution (rapid recolonisation)

POLICIES

- Administrative controls - policy making
  - Laboratory facilities
  - Hygiene services
  - Staff training supported by guidelines

Staff education is vital for patient and occupational safety

"Implementing changes to workflow may not result in changes if staff cannot embed new processes in everyday practice"

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Sink, drain and infection

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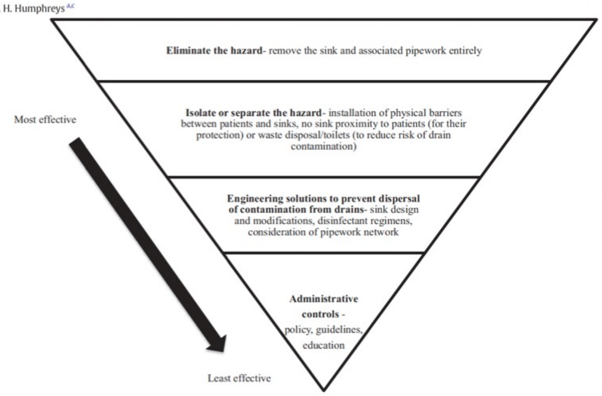

Fig. 2. The hierarchy of control interventions to decrease the risk of CPB dispersal from sinks, ranked from most to least effective when viewed as standalone measures.

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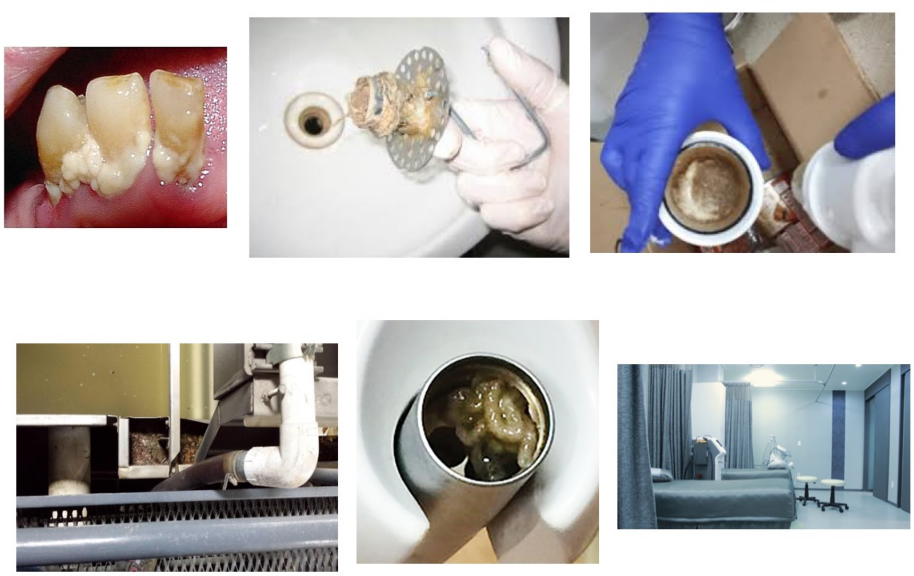
Biofilms



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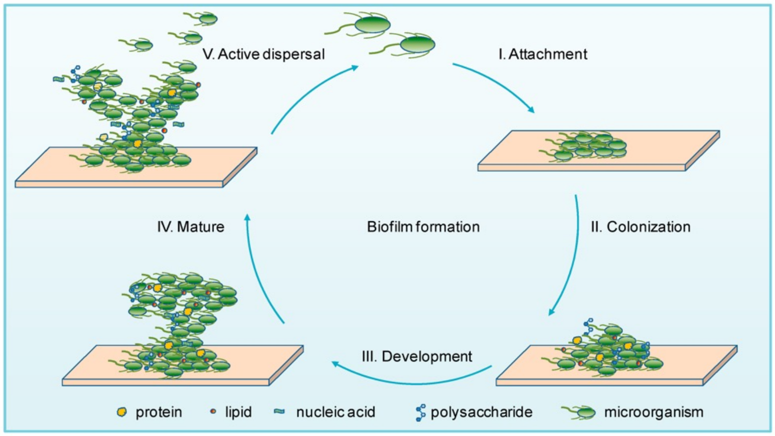
Biofilms



Int. J. Mol. Sci. 2019, 20(14), 3423; https://doi.org/10.3390/ijms20143423

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Biofilm resistance to antimicrobials

- Barrier to penetration
  - Diffusion gradient
  - Neutralisation
- Low metabolism
  - Nutrient/ O_2 gradients
  - Persister cells
- Bacterial species – diversity
  - Bacterial nature (presence of endospores)
  - Protection mechanisms
- Resistance mechanisms
  - Catalase + other enzymes
  - Efflux
  - Gene exchange

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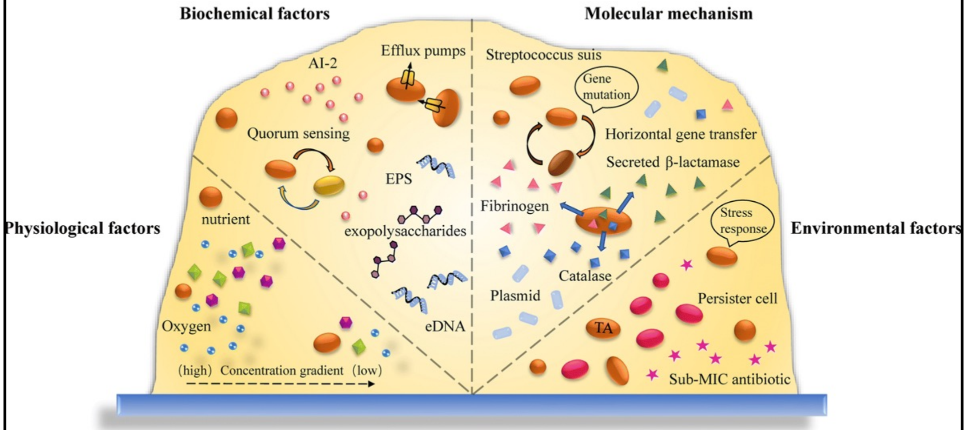
Biofilm resistance to antimicrobials



Yi, L., Jin, M., Li, J. *et al. Appl Microbiol Biotechnol* **104,** 8649–8660 (2020). https://doi.org/10.1007/s00253-020-10873-9

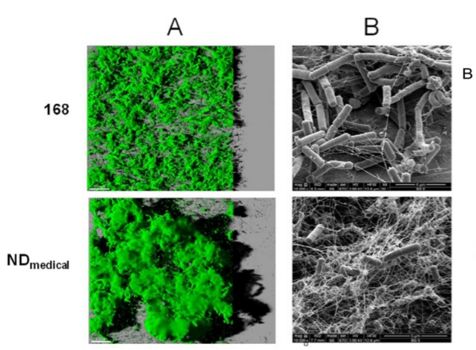
Biofilm resistance to antimicrobials

OPEN ACCESS Freely available online PLOS ONE

Biofilms of a *Bacillus subtilis* Hospital Isolate Protect *Staphylococcus aureus* from Biocide Action

Arnaud Bridier[1,2], Maria del Pilar Sanchez-Vizuete[1,2], Dominique Le Coq[1,2,3], Stéphane Aymerich[1,2], Thierry Meylheuc[1,2], Jean-Yves Maillard[4], Vincent Thomas[5], Florence Dubois-Brissonnet[1,2], Romain Briandet[1,2]

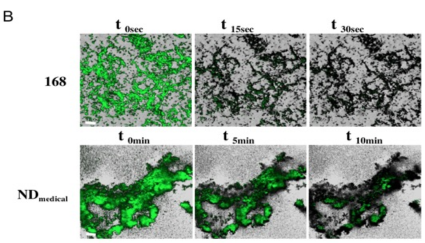
1 INRA, UMR 1319 MICALIS, Jouy-en-Josas, France, 2 AgroParisTech, UMR MICALIS, Jouy-en-Josas, France, 3 CNRS, Jouy-en-Josas, France, 4 Welsh School of Pharmacy, Cardiff University, Cardiff, United Kingdom, 5 STERIS, Fontenay aux Roses, France



Architecture of *B. subtilis* (vegetative) communities

Biofilms of a *Bacillus subtilis* endoscope WD isolate that protect *Staphylococcus. aureus* from peracetic acid

Susceptibility of *B. subtilis* (vegetative) to peracetic acid (500 ppm)



Visualization of Chemchrome V6 fluorescence loss (membrane permeabilisation) following treatment with PAA 500 ppm

Biofilm resistance to antimicrobials

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

OPEN ACCESS Freely available online PLOS | ONE

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1 INRA, UMR 1319 MICALIS, Jouy-en-Josas, France, 2 AgroParisTech, UMR MICALIS, Jouy-en-Josas, France, 3 CNRS, Jouy-en-Josas, France, 4 Welsh School of Pharm Cardiff University, Cardiff, United Kingdom, 5 STERIS, Fontenay aux Roses, France

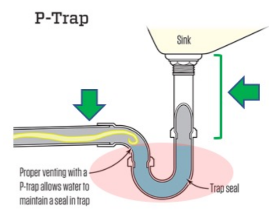
Table 2. Bactericidal activity of water and 0.35% PAA on single and mixed species biofilms after 5 min of treatment.

		log (CFU/well)	
	Strain	**Water**	**PAA (0.35%)**
Single species biofilm	*B. subtilis* 168	7.6±0.2	–
	B. subtilis NDmedical	7.7±0.1	3.9±0.6
	S.aureus AH478	9.3±0.1	–
Mixed species biofilm	*B. subtilis* 168	7.5±0.5	–
	S.aureus RN4220	8.2±0.4	–
	B. subtilis NDmedical	7.3±0.3	3.9±0.3
	S.aureus RN4220	8.4±0.1	2.6±0.5

Data shown are mean of three experiments ± standard deviation. Samples from which no survivor were recovered are represented by (–). Minimum detection of 2 logs CFU/well.
doi:10.1371/journal.pone.0044506.t002

Sink drain biofilms

- Wet/hydrated biofilm in sink u-bent (P-trap) or trap
- Partially dry biofilm at the front and back sections of drainage system; occasionally wetted
- Mainly *in situ* evidence for effectiveness of products in controlling drain biofilms
- Lack of information on biofilm regrowth
    - Observation : rapid recolonisation



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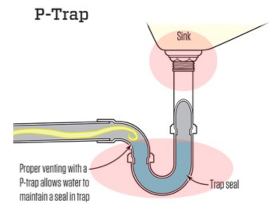
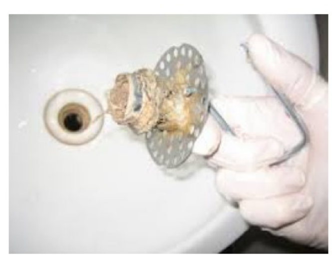
Sink drain biofilms

- Impact of strainer
    - Increases splashes - droplets
    - Strainer contamination
    - Not always considered
    - Difficult to clean/disinfect





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Sink drain biofilms

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Available online at www.sciencedirect.com
Journal of Hospital Infection
journal homepage: www.elsevier.com/locate/jhin

Carbapenem-resistant Enterobacteriaceae dispersal from sinks is linked to drain position and drainage rates in a laboratory model system

P. Aranega-Bou [a,*], R.P. George [b], N.Q. Verlander [c], S. Paton [a], A. Bennett [a], G. Moore [a], TRACE Investigators' Group [i]
[a] Biosafety, Air and Water Microbiology Group, National Infection Service, Public Health England, Salisbury, UK
[b] Manchester University NHS Foundation Trust, Manchester, UK
[c] Statistics Unit, Statistics, Modelling and Economics Department, National Infection Service, Public Health England, Colindale, UK

Table II
Dispersal from sinks known to be colonized with carbapenem-resistant Enterobacteriaceae (CRE) in the waste trap and drain

Distance from sink (cm)		Number of CRE detected using settle plates (Total sfu)									
		Fast drainage					Slow drainage				
		Around sink	0–27	27–54	54–100	Total	Around sink	0–27	27–54	54–100	Total
Drain underneath faucet (Sink A)	Flush 1	30.3	18.3	6.3	4	69.5	224	96	36.6	17	536.5
	Flush 2	2.7	1	6.6	0.3		106	34.3	17.3	5.3	
Drain at rear (Sink B)	Flush 1	0	0	0	0.3	0.3	14.3	0.6	0	0	18.5
	Flush 2	0	0	0	0		3	0.3	0.3	0	

Mean ($N = 3$ replicate experiments) number of splash-forming units (sfu) detected on settle plates placed immediately around the sink and at distances up to 1 m from the sink during two consecutive 30-s flushes.

Sink drain biofilms

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

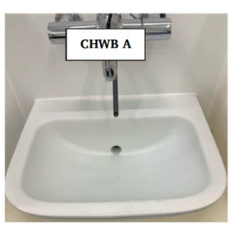
Journal of Hospital Infection 114 (2021) 171–174
Available online at www.sciencedirect.com
Journal of Hospital Infection
journal homepage: www.elsevier.com/locate/jhin

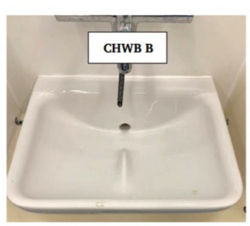
Short Report

A splash-reducing clinical handwash basin reduces droplet-mediated dispersal from a sink contaminated with Gram-negative bacteria in a laboratory model system

P. Aranega-Bou [a,*], C. Cornbill [a], N.Q. Verlander [b], G. Moore [a]
[a] Biosafety, Air and Water Microbiology Group, National Infection Service, Public Health England, Salisbury, UK
[b] Statistics Unit, Statistics, Modelling and Economics Department, National Infection Service, Public Health England, Colindale, UK

- Dispersal of Gram-negative bacteria from a conventional, rear-draining clinical handwash basin (CHWB) and a 'splash-reducing' CHWB with and/or without impaired drainage.





Sink drain biofilms

Journal of Hospital Infection 114 (2021) 171–174
Available online at www.sciencedirect.com
Journal of Hospital Infection
journal homepage: www.elsevier.com/locate/jhin

Short Report

A splash-reducing clinical handwash basin reduces droplet-mediated dispersal from a sink contaminated with Gram-negative bacteria in a laboratory model system

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- "splash-reducing" basin includes
  - hydrofin combined with the larger surface area of the basin reducing droplet production
  - a hydrophilic glaze.
  - design of the drainage pipe allowing fast drainage of water (eliminating dip that could retain water)
  - narrow rim of the basin (reducing occurrence of personal and patient care item placed around the basin
- 'splash-reducing' CHWB had significantly lower odds of spreading contamination than the conventional CHWB.

Sink drain biofilm trap model

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It's a trap! The development of a versatile drain biofilm model and its susceptibility to disinfection

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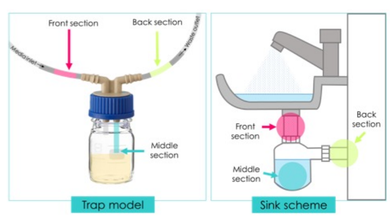
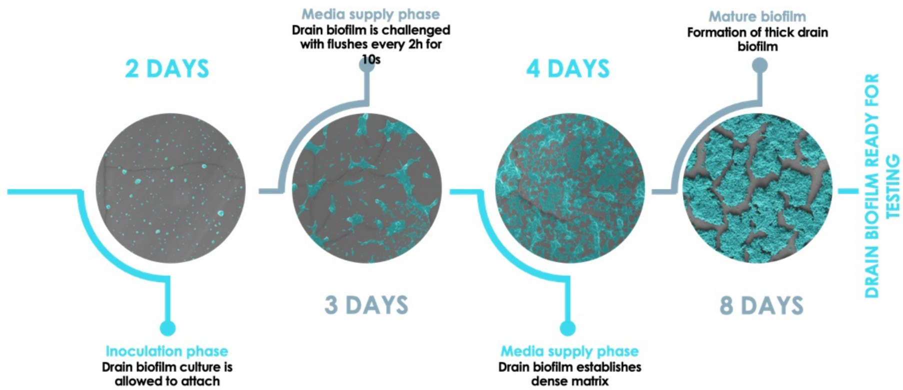


- **Mixed species** drain culture collected from a communal sink
- A peristaltic pump perfuse diluent, diluted growth medium, or biocidal products through the tube
- 1:10 TSB for growth promotion

Sink drain biofilm trap model



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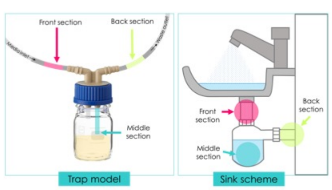
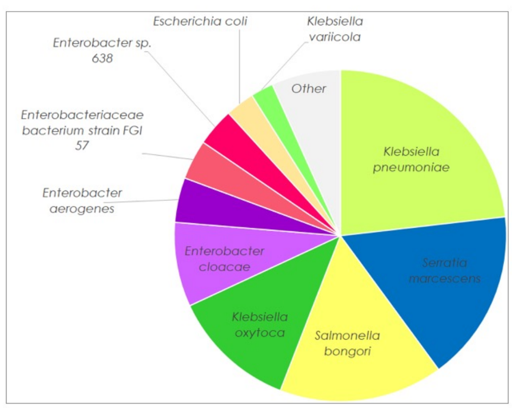
Sink drain biofilm trap model





Example of biofilm composition from the small-scale drain model

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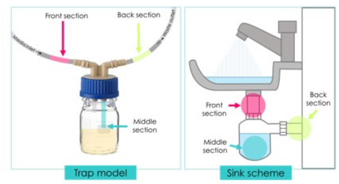
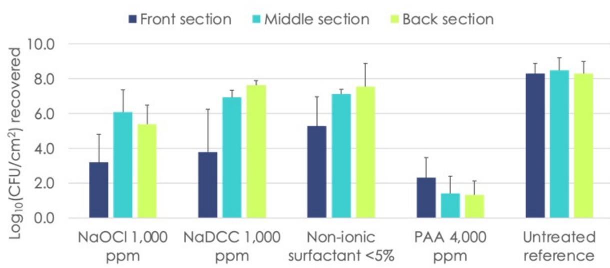
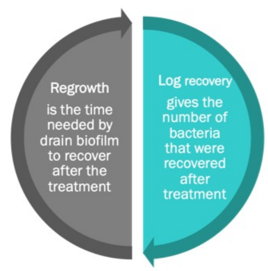
Sink drain biofilm trap model

- **Disinfection test**
  - Drain biofilm bacteria recovered following product treatment (3x 15 min doses)







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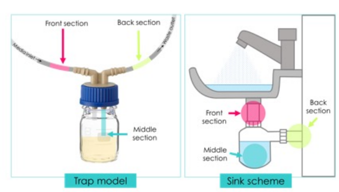
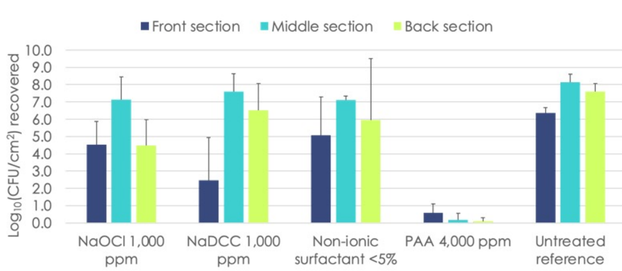
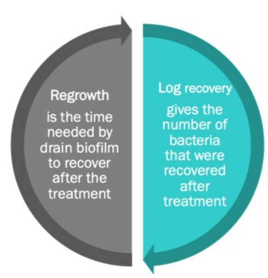
Sink drain biofilm trap model

- **Regrowth test**
  - Drain biofilm bacteria recovered 4 days after the product treatment (3x 15 min doses)







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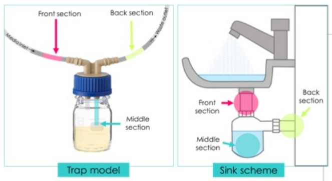
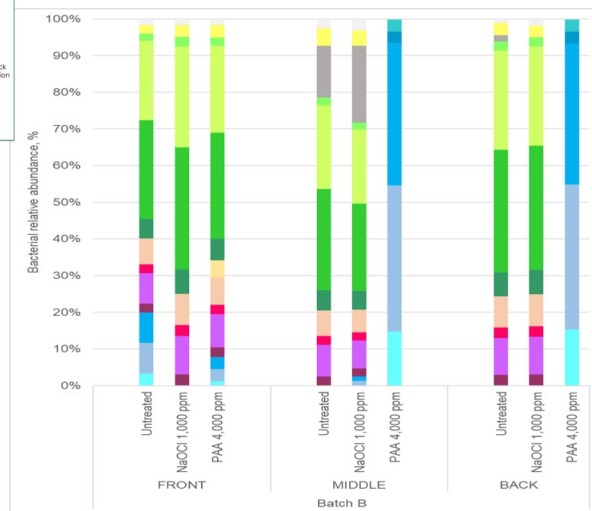
Sink drain biofilm trap model



Biofilm composition from the small-scale drain model after treatment & regrowth



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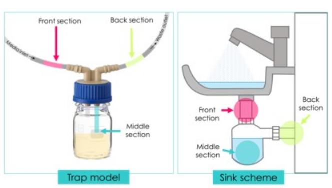
Sink drain biofilm trap model

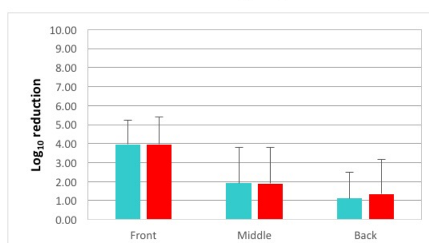


- Exploring *Pseudomonas aeruginosa* in a complex biofilm
  - 0.1-fold *P. aeruginosa* : drain ratios

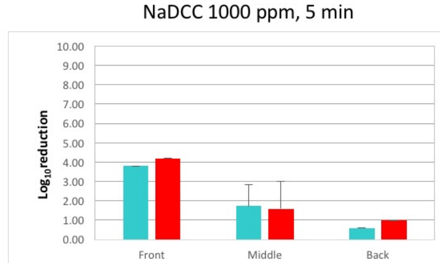
■ *P. aeruginosa* (Cetrimide agar)

■ All species (Tryptone Soy agar)

NaOCl 1000 ppm, 5 min



NaDCC 1000 ppm, 5 min



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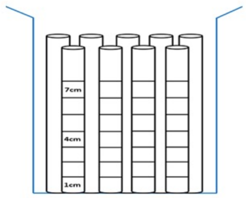
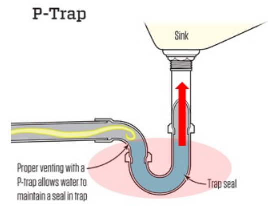
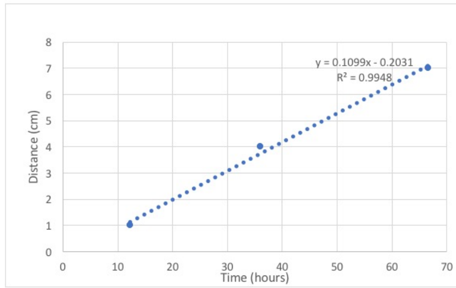
Sink drain biofilms

- How fast *Pseudomonas aeruginosa* colonise drain?
  - Upward motility over 72 h in support growth medium
  - Start up 4 or 6 $\log_{10}$ (10,000 or 1,000,000 bacteria/ mL)





- Speed
  - 0.11 cm/h over 72 h (4 lo$_{g10}$ start up)
  - 0.10 cm/h over 72 h (6 $\log_{10}$ start up)



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Sink, drain and infection

- Trap is a perfect environment for microbial growth
- Biofilm in trap very difficult to control/ eradicate
- The drain biofilm recovers quickly even after effective treatment
- Composition of the drain unchanged after NaOCl treatment

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Sink, drain and infection

- Sinks and drains responsible for pathogens transmission during outbreaks
- Most outbreaks can be controlled with a series of measures:
  - sink replacement
  - room design modifications
  - preventing splashing
  - repeated and frequent use of bleach
- Impossibility of eradicating sink contamination
- Prevention of outbreak recurrence by implementing routine disinfection of the sinks

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Thank you for listening

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June 28, 2022	(European Teleclass) HOW EFFECTIVE ARE INTERVENTIONS TO IMPROVE CLEANING OF HEALTHCARE ENVIRONMENTS IN LOW-RESOURCED SETTINGS? Speaker: **Prof. Giorgia Gon**, London School of Hygiene and Tropical Medicine, UK
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