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The Role of Water in Transmission of HAI's

Municipal Water Supply

Water direct from the municipal provider is not sterile, nor does it need to be

It must simply meet the requirement to supply wholesome or potable water i.e. the water must be fit to drink and not harmful

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Waterborne Pathogens

Pathogenicity depends on:

Susceptibility

Route

Source

Image courtesy of Lars Klintwall Malmqvist

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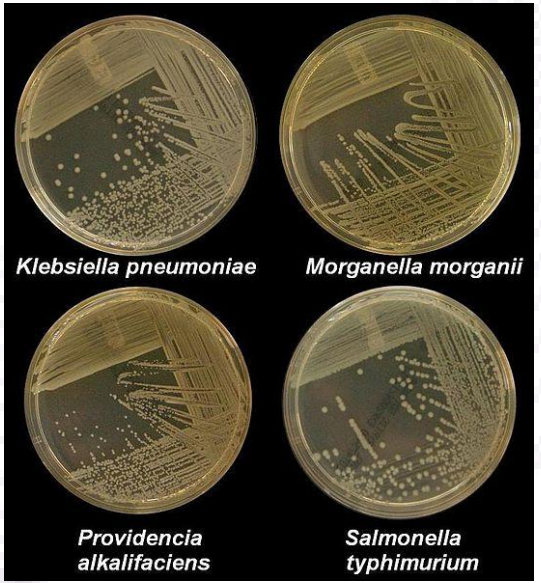
Waterborne Pathogens

Waterborne pathogens cause infections in health-care facilities;

- *Pseudomonas aeruginosa*
- *Stenotrophomonas maltophilia*
- *Chryseobacterium* species
- Non-tuberculous mycobacteria
- *Legionella* species
- *Mycobacterium avium* complex (MAC)
- *Fusarium*
- *Cryptosporidium*
- Viruses



Transmission occurs via contact, ingestion, aspiration; or aerosolisation of potable water; or via the hands of health-care workers

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Squier C, Yu VL, Stout JE. Cur Infect Dis Rep. 2000 Dec;2(6):490-496
Image courtesy of Eukaryotica

Pseudomonads

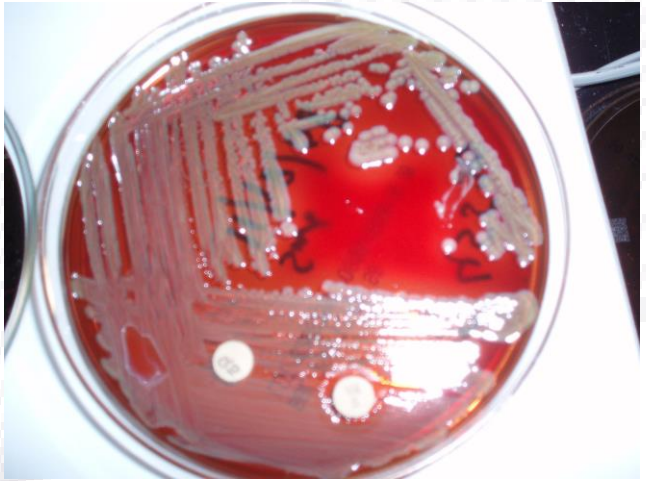
The taxonomy of many bacterial species has been recently redefined:

- The genus *Pseudomonas* now includes strains formerly classified in the genera *Chryseomonas* and *Flavimonas*
- Other strains previously classified in the genus *Pseudomonas* are now classified in the genera *Burkholderia, Ralstonia and Stenotrophomonas*

Elizabethkingia meningoseptica

Formerly *Flavobacterium* and *Chryseobacterium*:

- 22 month ICU outbreak
- Difficult to culture and misidentification
- MALDI-ToF
- Found in taps (biofilm producer)
- 3 x automatic daily flush



Moore *et al* EID 2016; 22 (1): 9-17
Image courtesy of Dr. Saptarshi

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Surveillance

Pseudomonas spp. and *Stenotrophomonas* spp. bloodstream infections during 2007-2014 in England, Wales and Northern Ireland.

Extracted from PHE voluntary surveillance database.

https://www.gov.uk/government/uploads/system/.../hpr2515_psdmns.pdf

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Infection Rates

Pseudomonas spp. 11% decrease

Stenotrophomonas spp. 36% decrease

https://www.gov.uk/government/uploads/system/.../hpr2515_psdmns.pdf

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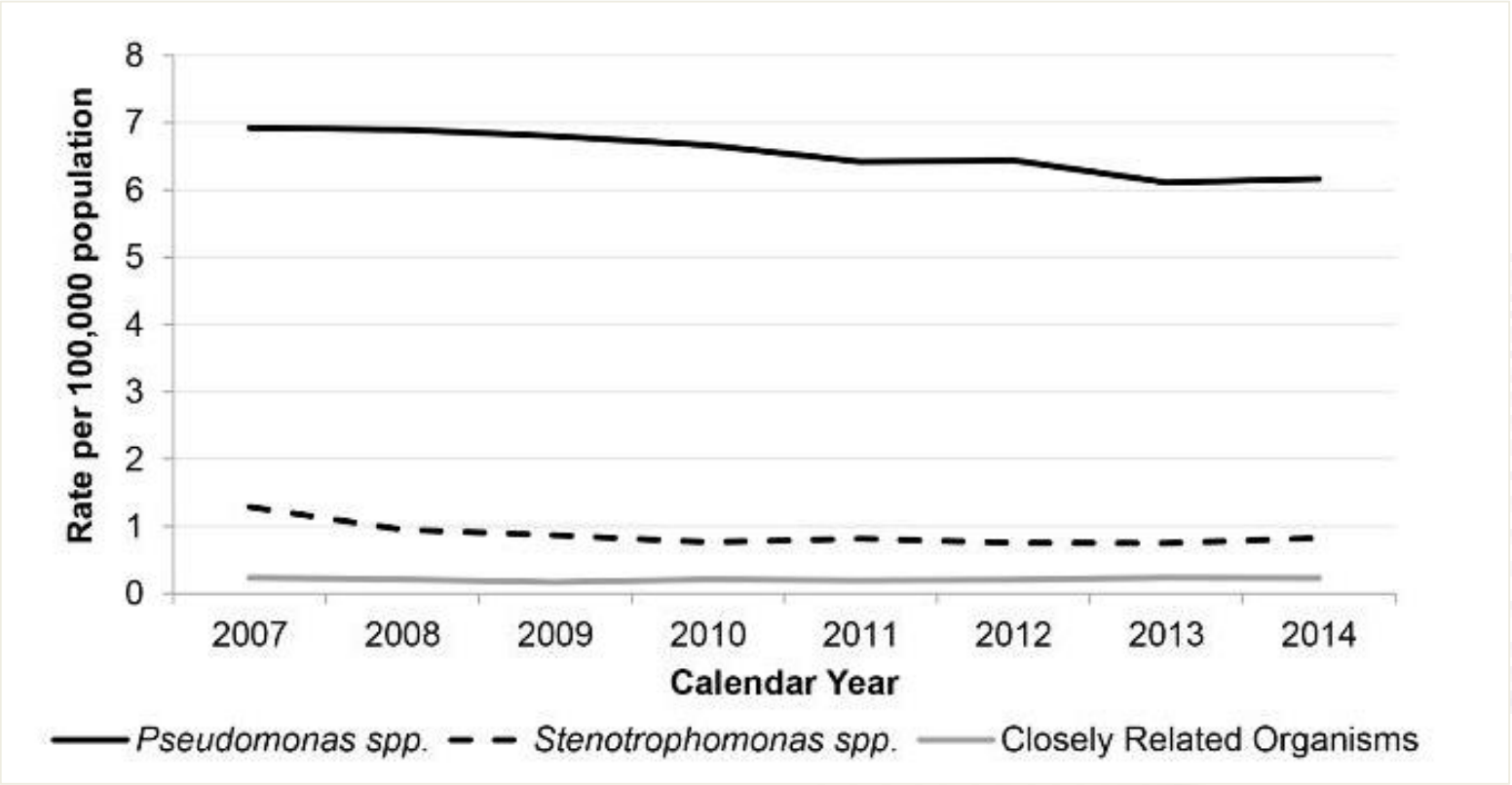

Figure 1. Eight year trend in *Pseudomonas* spp., *Stenotrophomonas* spp. and closely related species bacteraemia reports per 100,000 population (England Wales and Northern Ireland); 2007 to 2014

https://www.gov.uk/government/uploads/system/.../hpr2515_psdmns.pdf

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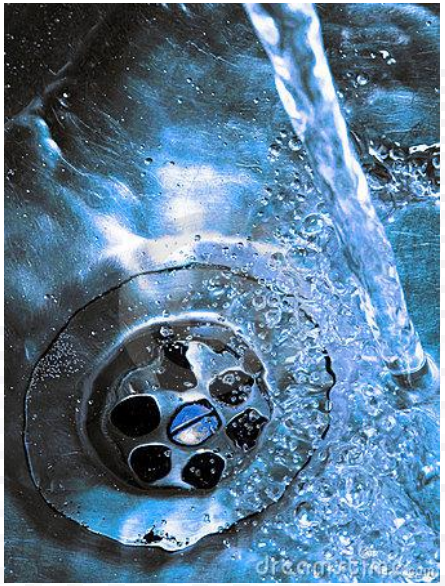
Resistance

Steady increase to imipenem and piperacillin/tazobactam

https://www.gov.uk/government/uploads/system/.../hpr2515_psdmns.pdf

Antibiotic Resistance



Highest MDR indices were mainly from hospital effluent:

- *Acinetobacter*
- *Aeromonas*
- *Citrobacter*
- *Enterobacter*
- *Klebsiella*
- *Pseudomonas*

Bacteria are important vectors of antibiotic resistance and can be disseminated from hospital effluent to aquatic environments.

This is relevant to support management options aiming to control this public health problem.

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Vaz-Moreira *et al*. Microb Drug Resist. 2015 Oct 15. [Epub ahead of print]

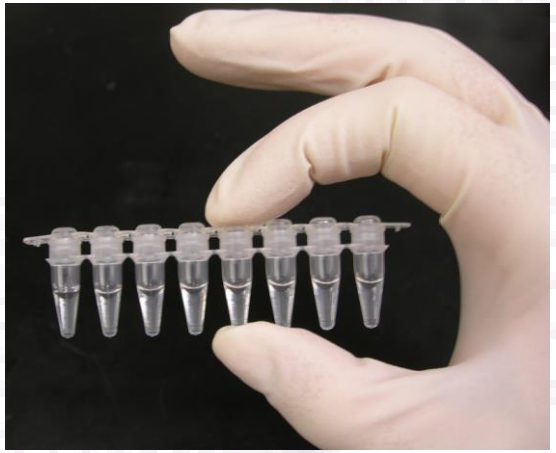
Non-Tuberculous Mycobacteria

- "*Legionella* spp. and *Mycobacterium avium* complex (MAC) are opportunistic pathogens of public health concern."
- "Hot water systems, including showers, have been identified as a potential source of infection."
- "Unhooking showerheads and allowing them to dry is not an effective method to reduce the risk of *Legionella* or MAC colonisation."

Whiley *et al.* Pathogens 2015, 4(3), 590-598; doi:10.3390/pathogens4030590
Image courtsy of Frank C. Müller

Non-Tuberculous Mycobacteria

- “Reliance on culture-based methods exaggerates treatment efficacy and reduces our ability to identify pathogens”
- “Next-generation sequencing and PCR approaches are on the cusp of changing that.”
- “Water-based *Legionella* and NTM probably dominate health burden following the various societal uses of drinking water.”



Ashbolt. Curr Environ Health Rep. 2015; 2(1): 95–106
Image courtesy of Madeleine Price Ball

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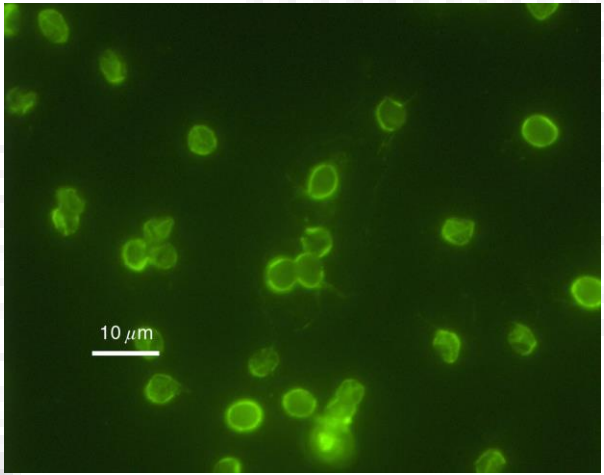
Parasites

- High prevalence of intestinal parasites in ESRD patients undergoing hemodialysis
- For immunocompromised, we suggest stool examination for intestinal parasites, with an emphasis on detection of *Cryptosporidium* spp. and *Blastocystis*
- Measures for preventing the acquisition of IPI's are also recommended



Omrani *et al*. Infection. 2015 Oct;43(5):537-44. doi: 10.1007/s15010-015-0778-6. Epub 2015 Apr 14
Image credit: EPA/H.D.A. Lindquist

Fungi

- "Fungal outbreaks still occur in healthcare settings, especially among patients who are immunocompromised."
- "The causative pathogens were usually *Aspergillus* species, but *Zygomycetes* and other fungi were occasionally reported"
- "Performing infection control risk assessments and implementing recommended control measures is essential to prevent healthcare-associated fungal outbreaks during construction and renovation."

Kanamori *et al*. Clin Infect Dis 2015 61: 433-444

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Fungi

"The results allowed us to conclude that we were in the presence of fungal strains of *Fusarium* particularly suited to a life in water."

Sautour *et al*. http://dx.doi.org/10.1016/j.mycmed.2015.02.002
Image courtesy of CDC/Dr. Libero Ajello (PHIL #4011), 1978

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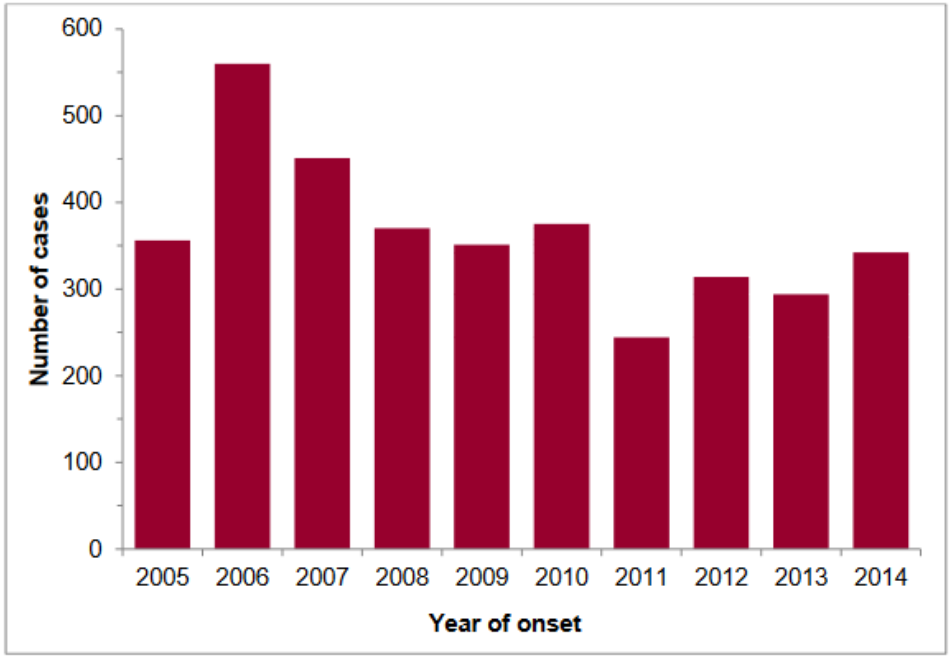
Legionnaires' Disease

Figure 1: Number of cases of Legionellosis (confirmed and presumptive) in residents of England and Wales by year of onset, 2005 to 2014



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https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/439589/Legionnaires_Disease_in_England_and_Wales_2014.pdf

Legionnaires' Disease

Table 4: Number of confirmed Legionnaires' disease cases by category of exposure and year of onset, 2012 to 2014

Category	Community* (%)	Nosocomial (%)	Travel abroad (%)
2012	168 (54.9)	11 (3.6)	127 (41.5)
2013	192 (67.4)	5 (1.8)	88 (30.9)
2014	186 (56.2)	6 (1.8)	139 (42.0)

* Includes cases who travelled within the UK

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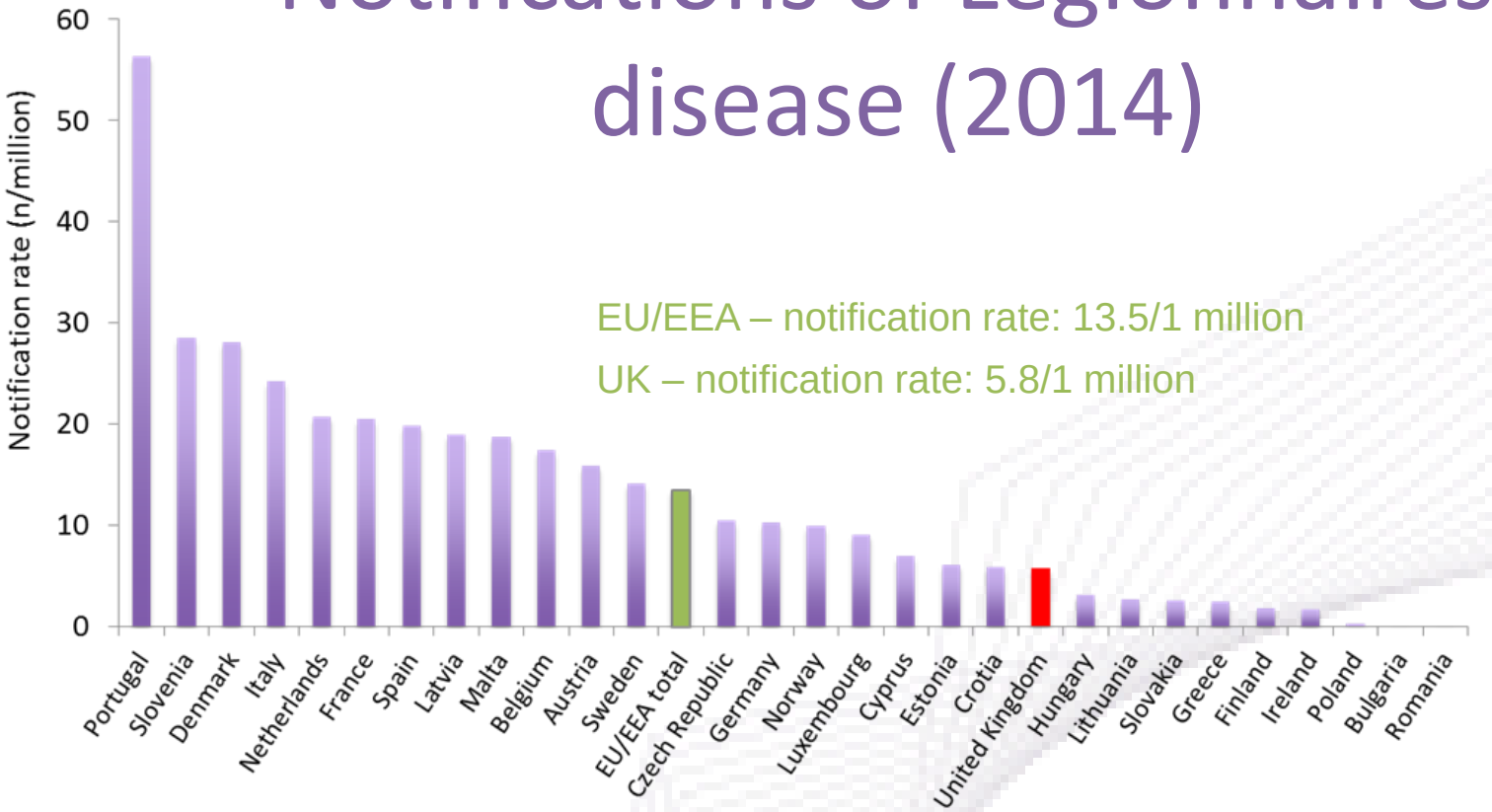
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/439589/Legionnaires_Disease_in_England_and_Wales_2014.pdf

Notifications of Legionnaires' disease (2014)



EU/EEA – notification rate: 13.5/1 million

UK – notification rate: 5.8/1 million

Source data: ecdc.europe.eu

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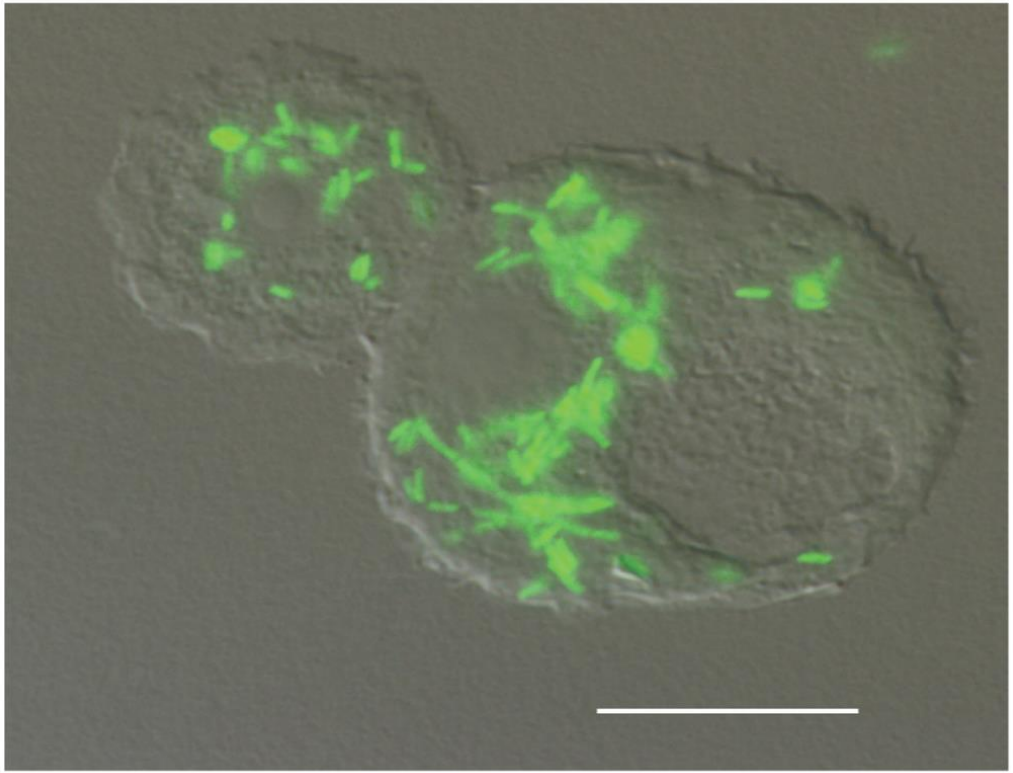
Amoebae



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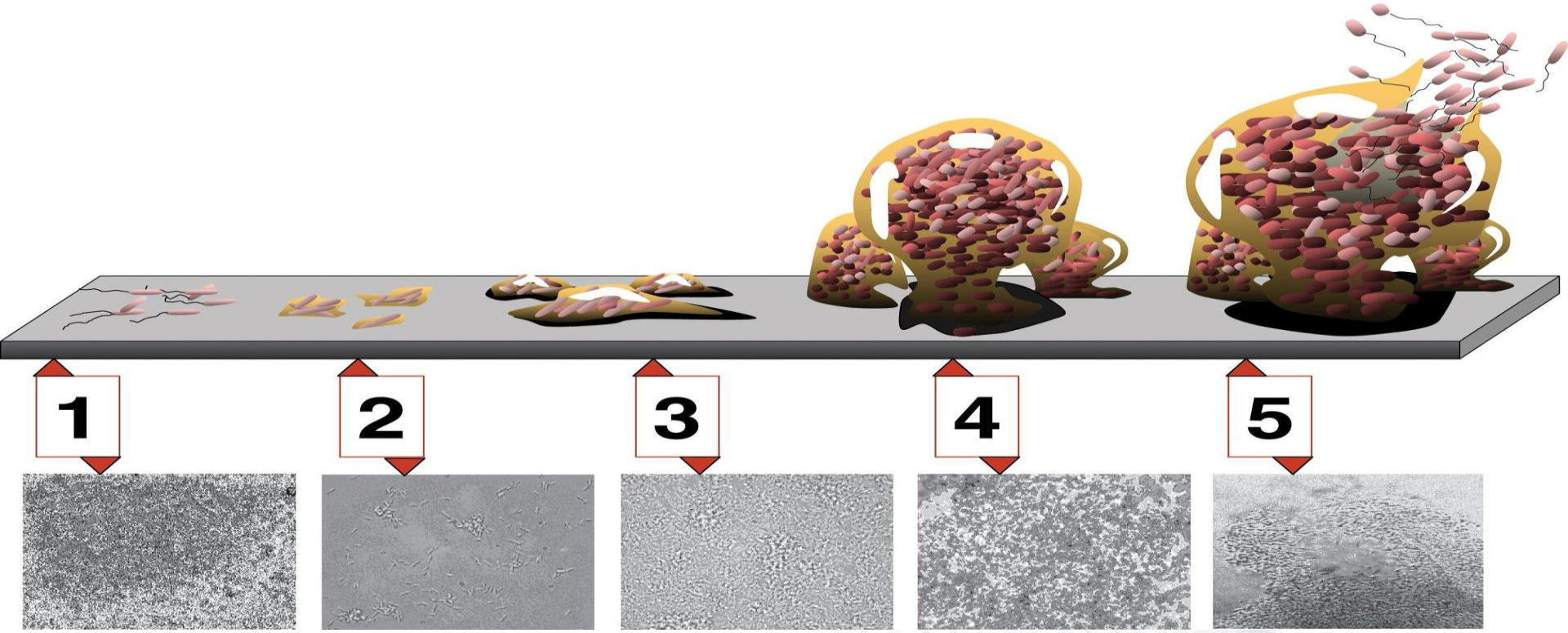
Abdel-Nour *et al* Int. J. Mol. Sci. 2013, 14(11), 21660-21675; doi:10.3390/ijms141121660



Five stages of biofilm development: (1) Initial attachment, (2) Irreversible attachment, (3) Maturation I, (4) Maturation II, and (5) Dispersion. Each stage of development in the diagram is paired with a photomicrograph of a developing *P. aeruginosa* biofilm. All photomicrographs are shown to same scale

http://commons.wikimedia.org/wiki/File:Biofilm.jpg#/media/File:Biofilm.jpg

Sources of Biofilm

- Contamination during construction and repair of WDS
- Unsuitable materials of construction
- Uncontrolled temperatures/chemicals
- Stagnation of water
- Poor design
- Low use of outlets and deadlegs
- Poor hygiene at points of use

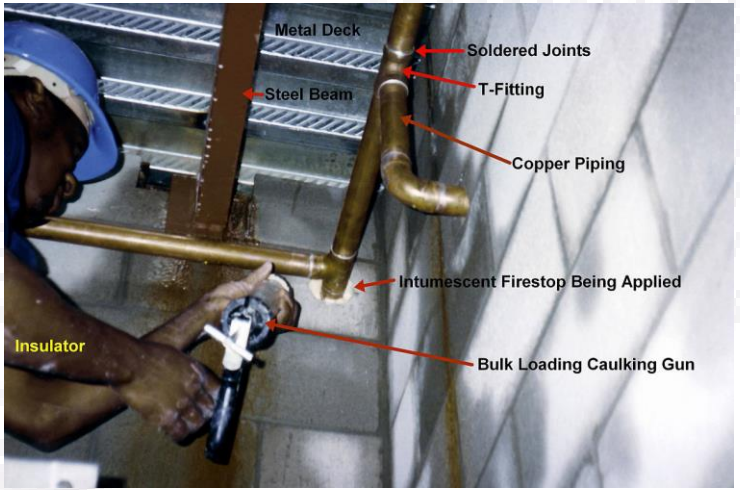


Image courtesy of Achim Hering

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Biofilm and VBNC

- Biofilm can protect the bacteria from the control treatment
- Bacteria can become stressed and unable to multiply (so not appearing on plate counts) but are still viable i.e. Viable But Not Culturable (VBNC)
- Once the reasons for the stress are removed then growth can resume

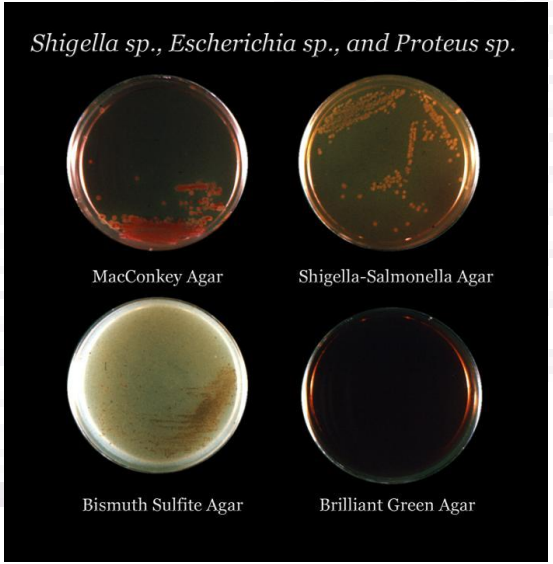

Image source: Centers for Disease Control and Prevention Public Health Image Library

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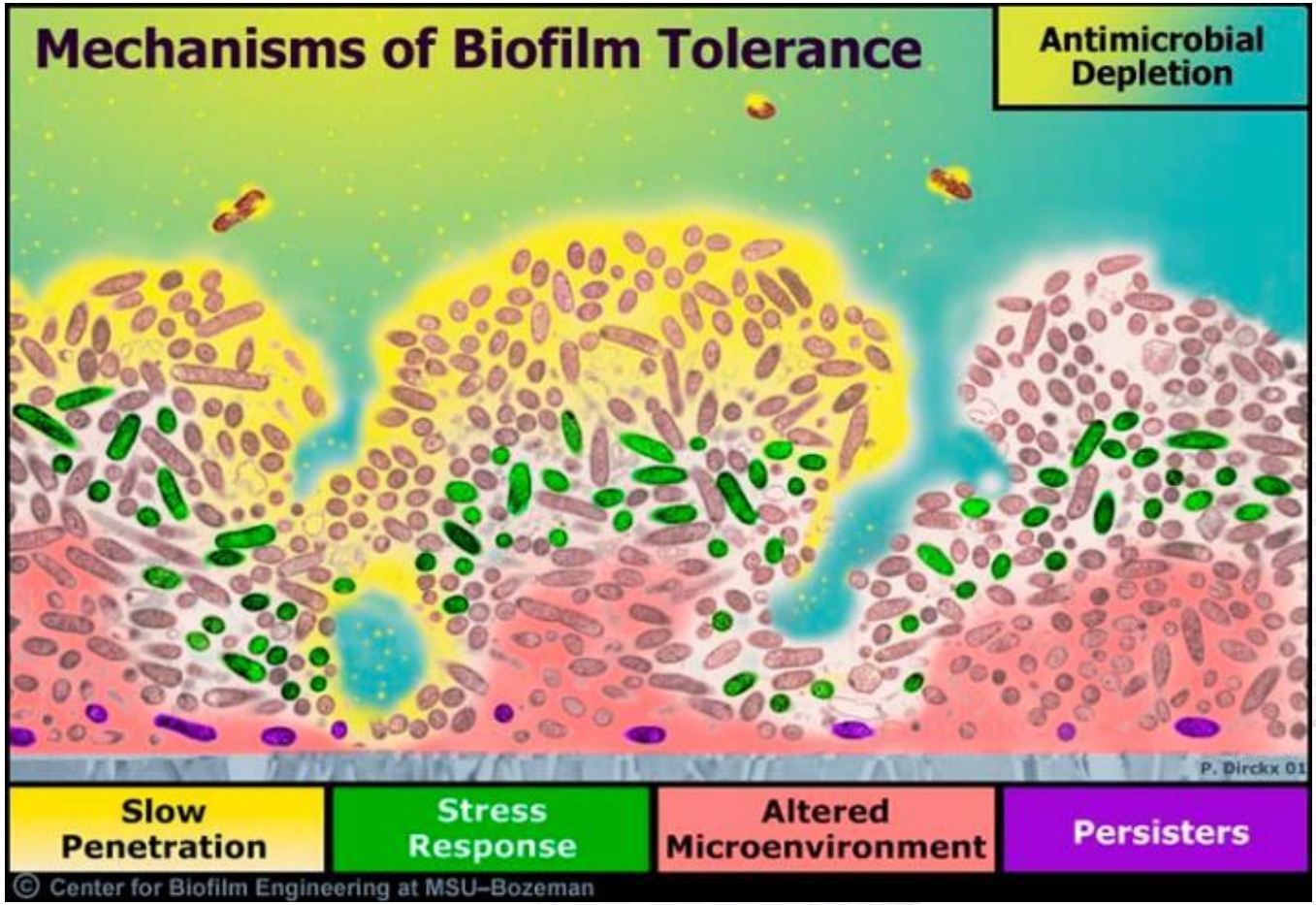

https://www.biofilm.montana.edu/resources/images/biofilm-resistance/5-mechanisms-antimicrobial-tolerance.html

Biofilm and VBNC

"Resuscitation is still possible using amoeba and may become infectious for human cell lines following a previous interaction with *A. polyphaga*."

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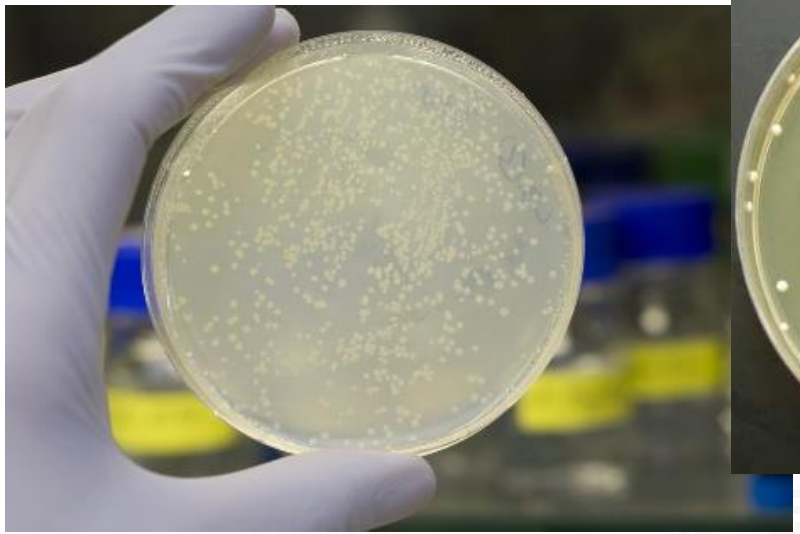
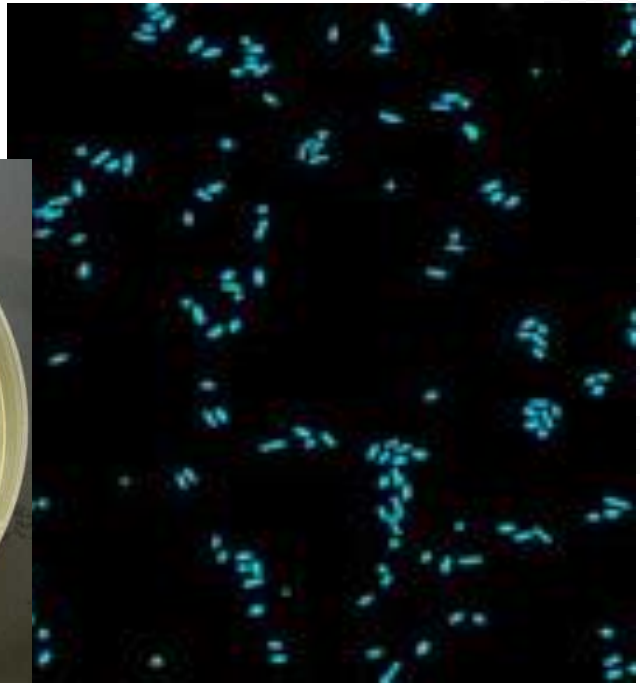
Epalle *et al.* Microb Ecol. 2015 Jan;69(1):215-24. doi: 10.1007/s00248-014-0470-x. Epub 2014 Jul 30

Image courtesy of

Identification

Bacterial numbers depend on test method





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Images courtesy of Prof HC Flemming, Biofilm Centre, Essen

Amoeba Resistant Microbes

- *Legionella* spp
- *Pseudomonas* spp
- *Stenotrophomonas maltophilia*
- *Acinetobacter* spp
- NTMs
- *Segniliparus* spp
- *Methylobacterium* spp
- *Aeromonas hydrophila*
- *Cronobacter* spp
- *Helicobacter pylori*
- *Simkania negevensis*

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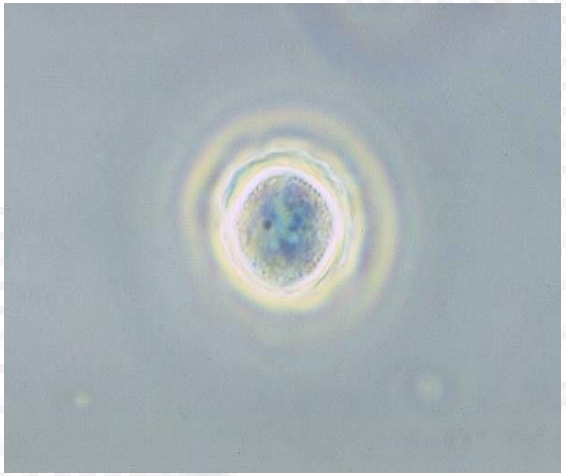
Amoeba Resistance

Legionella-amoeba association reduced effectiveness of treatments:

- At the lowest free chlorine concentration, 0.5 mg/L
- At the lowest temperatures, 50°C & 55°C

Increased health risk **close to the tap** where lower free chlorine concentrations and lower temperatures are commonly observed.



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Cervero-Aragó *et al,* PLoS One. 2015 Aug 4;10(8):e0134726. doi: 10.1371/journal.pone.0134726. eCollection 2015

Image courtesy of CDC/ Dr. George Healy

Resistance

Not all opportunistic pathogens are equally resistant to disinfectants, temperature and low oxygen:

- *M. avium* is the most resistant to chlorine
- *P. aeruginosa* can grow under anaerobic conditions
- Numbers of *E.coli* fall as they move from source
- Numbers of opportunistic pathogens increase

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Falkinham J. Int J Environ Res Public Health. 2015 Apr 24;12(5):4533-4545

Image courtesy of SODIS Eawag

Table 1. Chlorine resistance of waterborne pathogens relative to *Escherichia coli*.

Genus or Species	$CT_{99.9\%}$ [a]	Reference
Escherichia coli	0.09 (reference)	Taylor *et al.* (2000) [12]
Legionella pneumophila		
Medium-grown	7.5 (83-fold)	Kuchta *et al.* (1985) [9]
Water-adapted	52.5 (580-fold)	Kuchta *et al.* (1985) [9]
Mycobacterium avium		
Medium-grown	51 (567-fold)	Taylor *et al.* (2000) [12]
Water-adapted		Steed and Falkinham (2006) [13]
Pseudomonas aeruginosa	1.92 (21-fold)	Grobe *et al.* (2001) [14]
Methylobacterium spp.	1.5 (16.7-fold)	Furuhata *et al.* (1989) [15]
Acinetobacter baumanii	59 (658-fold)	Karumathil *et al.* (2014) [16]
Aeromonas hydrophila	2.6 (29-fold)	Sisti *et al.* (1998) [17]

[a] Product of concentration (mg/L) and duration of exposure (min) to kill 99.9% of cells.

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Falkinham J. Int J Environ Res Public Health. 2015 Apr 24;12(5):4533-4545.

Holistic Approach

- Water treatments shouldn't be considered in isolation – many work better in conjunction with one another
- This is the same for the management of water distribution systems – a team approach is vital

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Holistic Approach

"Because broadly effective community-level engineering interventions for the control of OPPPs have yet to be identified, and because the number of at-risk individuals will continue to rise, it is likely that OPPP-related infections will continue to increase."

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Falkinham *et al*. Environ Health Perspect. 2015 Aug;123(8):749-58. doi: 10.1289/ehp.1408692. Epub 2015 Mar 20.

Holistic Approach

"New and emerging pathogens, novel pathogen detection methods, and hidden reservoirs of infection should hence be given special consideration when designing the layout of buildings and medical devices, but also when defining the core competencies for medical staff, establishing programmes for patient empowerment and education of the general public, and when implementing protocols for the prevention and control of infections in medical, community and domestic settings.

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Bloomfield *et al*. GMS Hyg Infect Control. 2015 Feb 4;10:Doc04. doi: 10.3205/dgkh000247. eCollection 2015.

Summary

- Municipal water is not sterile
- Pathogenicity depends on susceptibility, route and source
- Culture may not give true representation of contamination
- “Not Detected” does not mean complete absence of target
- Waterborne organisms are varied
- Organisms can become resistant to chemicals and antibiotics
- One treatment does not fit all
- New guidance recognises the importance of a team approach

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