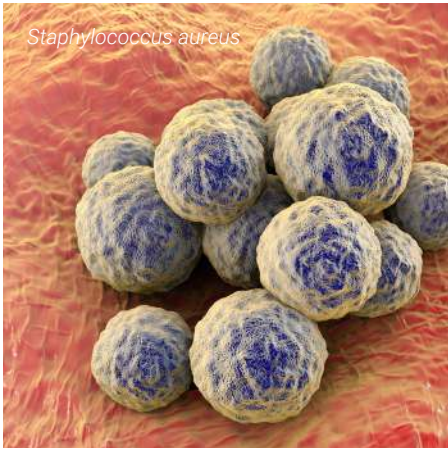
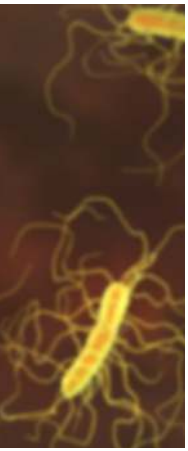
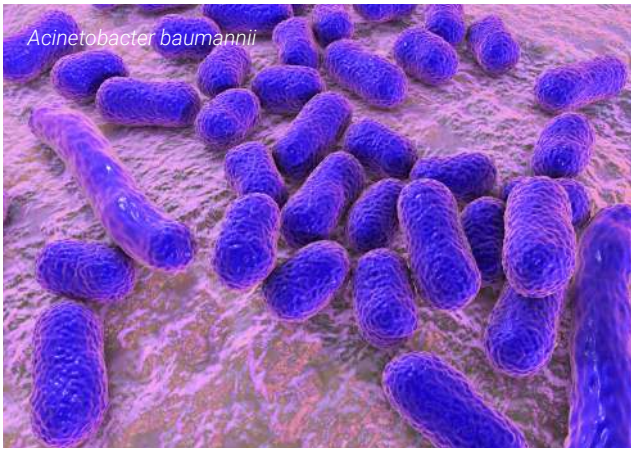




THE UVD ROBOTS GUIDE

for healthcare associated pathogens

Booklet version 2021-04



UVD ROBOTS

ABOUT THE AUTHOR

Professor Val Edwards-Jones - PhD, CSci, FIBMS

Val is Emeritus Professor of medical microbiology at Manchester Metropolitan University, UK; Visiting Professor of the Institute of Skin Integrity and Infection Prevention, Huddersfield University, UK; Visiting Professor of the Medical University, Perm, Russia: Clinical Director at MelBec Microbiology Ltd, Lancashire; an independent microbiology company, technical director of Microsan Ltd, a company producing natural cleaning products using essential oils and an Independent Microbiology Consultant of Essential Microbiology Ltd.

In her role as an independent microbiology consultant, work in 2020 to now (August 2020) has included advising on single use plastics and its impact on infection control, the impact of UV-C in reducing environmental decontamination, evaluation of an innovative method of microbial identification using FTIR, development of an innovative treatment for fungal nail infection, development of an on-line training programme for Legionella risk advice and National Advisory Committee for Antimicrobial Stewardship in Wound care.

A 45 year career in Microbiology, Val has 20 years experience in the NHS in diagnostic microbiology and 21 years as an academic researcher. Her research interests are wound infection, toxic shock syndrome, alternative treatment strategies, essential oils as antimicrobial agents and rapid diagnosis of infection using mass spectrometry.

She is consultant microbiologist for the television show "Embarrassing Bodies" and frequently advises on anything microbiological for a variety of TV programs and PR companies.

This booklet has been written to help infection preventionists, environmental services staff and healthcare cleaning professionals understand how UV-C delivered by a UVD Robot can rapidly kill priority pathogens typically found in hospitals and other healthcare environments.

Contents

World Health Authority Pathogens and how to kill them!

An introduction by Professor Val Edwards-Jones, PhD, CSci, FIBMS
Emeritus Professor Of Medical Microbiology, Manchester Metropolitan University, UK
Independent Microbiology Consultant, Essential Microbiology Ltd, UK

UV-C DISINFECTION AND INFECTION CONTROL

Innovation and technology has changed the landscape of modern medicine. Robots now routinely undertake certain operations within a healthcare setting and telemedicine has allowed a change to the tertiary healthcare systems. Modern medicine now focusses on disease prevention, cure, well-being and longevity. Technologies such as the bionic eye, implantable chips under the skin to hold the patients' medical records and sensors implanted into the body allowing continuous monitoring of certain parameters all promote better health for the population. An understanding of the human microbiome and its impact on patients health is something we see in futuristic movies, where modification of the symbiotic microorganisms can improve our health.

However, we did not foresee the rapid development of antibiotic resistance in common pathogens and perhaps the end of modern medicine as we know it. If we take away the ability to prevent and treat infectious disease which has killed millions of people over the millennia, then any risky healthcare procedure that requires antimicrobial cover may be prevented going forward.

We must think of a simple technology that keeps the healthcare environment safe to work within. For health and safety purposes, we are seeking an environment with low numbers of microorganisms to minimize risk to the people who work within an industry. Decontamination of water supplies is also essential and ultra violet (UV) light is used extensively in the water industry to produce clean sterile water for these purposes.

UV-C has a huge potential and future in healthcare, helping to decontaminate the environment without using harmful chemicals and polluting the water course. The electromagnetic spectrum is divided into seven regions ordered by decreasing wavelengths and increasing energy and frequency. These are radio waves, microwaves, infrared (IR) visible light, ultraviolet (UV), X-rays and gamma rays. Ultraviolet light falls in the range between visible light and X-rays. It can be subdivided into three sub-bands namely UVA (315nm-400nm), UVB (280-315nm) and UV-C (180-280nm). Most natural UV energy comes from the sun with 10% of sunlight being attributed to UV consisting of 95% UV-A and 5% UV-B.

There is no measurable UV-C energies from solar radiation on the earths' surface because ozone, oxygen and water vapour absorb it. UV-C can be produced artificially using lamps (usually vaporised mercury or other gas) that emit this radiation at a particular wavelength (254nm). UV-C, which has the shortest wavelength and the highest energy can act as a surface disinfectant and is less able to penetrate the skin.

HOW DOES UV-C KILL MICROORGANISMS?

All cells (including microbial cells) absorbs UV radiation through photons which cause ionisation of cellular substances including DNA. The principal mode of inactivation occurs when the absorption of a photon forms pyrimidine dimers through the formation of covalent linkages between consecutive bases along the nucleotide chain. This causes problems for both replication and transcription and hence are toxic and mutagenic to the cell. DNA repair mechanisms can reduce the lethal effect of UV, especially for viruses possessing double-stranded (ds) nucleic acids so dosage is important. UV-C also damages other cellular and viral components, causing, for example, photochemical reactions in proteins and enzymes.

ANTIMICROBIAL RESISTANCE

This phenomenon of multidrug-resistant (MDR) pathogens has increasingly become a cause for serious concern with regard to both nosocomial (hospital acquired) and community-acquired infections. Much of the resistance has been acquired by an array of microorganisms since the introduction of antibiotics and their over use. The beta lactams (penicillins and cephalosporins and their derivatives) remain the most widely used antibiotics because of their ease of use and low toxicity. These classes of antibiotic are still the drug of choice for many infections and unfortunately many bacterias have developed an easy way of avoiding the lethality by acquiring enzymes that break down these antibiotics; the beta lactamases.

As of 2018, the Centre for Disease Prevention and Control (CDC) is tracking carbapenemase enzymes in a wide range of organisms using data generated by the Antibiotic Resistance Laboratory Network (AR Lab Network) and CDC laboratories. The AR Lab Network routinely tests for the following carbapenemases:

- *K. pneumoniae carbapenemase (KPC): This was first identified in the United States around 2001 and is the most common carbapenemase in the United States*

- *New Delhi Metallo-beta-lactamase (NDM): A less common carbapenemase in the United States but concerning because it can be resistant to even more antibiotics than KPC*

- *Verona Integron-Enconded Metallo-beta-lactamase (VIM): A less common carbapenemase in the United States but concerning because it can be resistant to even more antibiotics than KPC*

- *Imipenemase (IMP): A less common carbapenemase in the United States but concerning because it can be resistant to even more antibiotics than KPC*

- *Oxacillinase-48-like (OXA-48-like): A less common carbapenemase in the United States*

Although this group of microorganisms are extremely important cause of health care associated infections there are other, less well known that also need prevention going forward.

Bacteria and fungi listed in the 2019 AR threats report

In 2013, CDC published the first AR Threats Report, which sounded the alarm to the danger of antibiotic resistance. The report stated that each year in the U.S. at least two million people get an antibiotic-resistant infection, and at least 23,000 people die due to complications from infection. The 2013 AR Threats Report helped inform the National Action Plan for Combating Antibiotic-Resistant Bacteria. The 2013 and 2019 reports do not include viruses (e.g., HIV, influenza) or parasites.

In addition, the World Health Organization (WHO) has identified antimicrobial resistance as one of the three most important problems facing human health and have listed 12 priority organisms that are antibiotic resistant and are causing problems across the globe. These have caused a large number of deaths and fatalities are expected to increase unless either new antibiotics can be found or new methods are introduced within infection control to help reduce the risk of acquiring these organisms.

The most common and serious multi-drug resistent (MDR) pathogens have been encompassed within the acronym "ESKAPE," standing for *Enterococcus faecium*, *Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa* and *Enterobacter spp*.

The WHO list is divided into three categories according to the urgency of need for new antibiotics: critical, high and medium priority. Organisms that are included in other programmes (e.g. tuberculosis) were excluded.

URGENT THREATS
Carbapenem-resistant Acinetobacter
Candida auris
Clostridium difficile spores
Carbapenem-resistant Enterobacteriaceae (CRE)
Drug-resistant Neisseria gonorrhoeae

SERIOUS THREATS
Drug-resistant Campylobacter
Drug-resistant Candida
ESBL-producing Enterobacteriaceae
Vancomycin-resistant Enterococci (VRE)
Multidrug-resistant Pseudomonas aeruginosa
Drug-resistant non typhoidal Salmonella
Drug-resistant Salmonella serotype Typhi
Drug-resistant Shigella
Methicillin-resistant Staphylococcus aureus (MRSA)
Drug-resistant Streptococcus pneumoniae
Drug-resistant Tuberculosis

CONCERNING THREATS
Erythromycin-Resistant Group A Streptococcus
Clindamycin-resistant Group B Streptococcus

WATCH LIST
Azole-resistant Aspergillus fumigatus
Drug-resistant Mycoplasma genitalium
Drug-resistant Bordetella pertussis

WHO priority pathogens list for R&D of new antibiotics

CRITICAL
Acinetobacter baumannii, carbapenem-resistant
Pseudomonas aeruginosa, carbapenem-resistant
Enterobacteriaceae, carbapenem-resistant, ESBL-producing

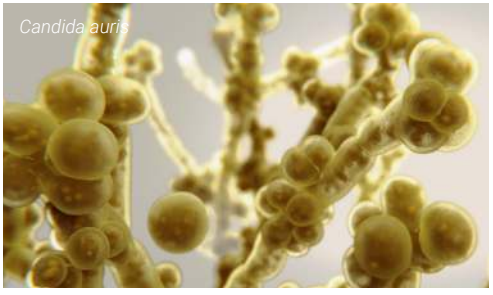
HIGH
Enterococcus faecium, vancomycin-resistant
Staphylococcus aureus, methicillin-resistant, vancomycin-intermediate and resistant
Helicobacter pylori, clarithromycin-resistant
Campylobacter spp., fluoroquinolone-resistant
Salmonella, fluoroquinolone-resistant
Neisseria gonorrhoeae, cephalosporin-resistant, fluoroquinolone-resistant

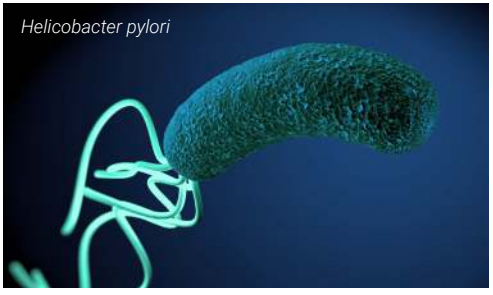
MEDIUM
Streptococcus pneumoniae, penicillin-non-susceptible
Haemophilus influenzae, ampicillin-resistant
Shigella spp., fluoroquinolone-resistant

IMPORTANT ORGANISMS CAUSING HEALTHCARE ASSOCIATED INFECTION
Candida auris
Clostridium difficile spores
Escherichia coli
Mycobacterium tuberculosis
SARS-Cov-2

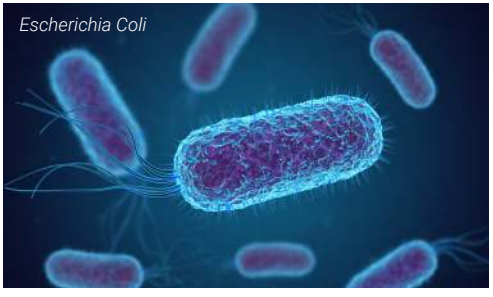
The Priority Pathogens

Our list of relevant bugs has been compiled based on the three categories in the World Health Organization's pathogen priority list and additional organisms known to be causing problems in healthcare settings.

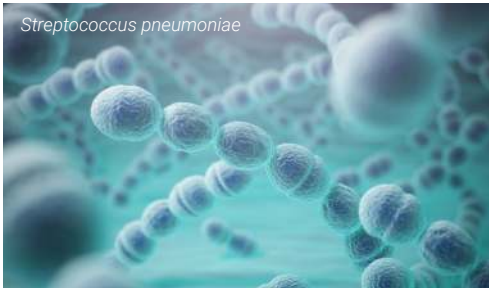

Candida auris


Helicobacter pylori

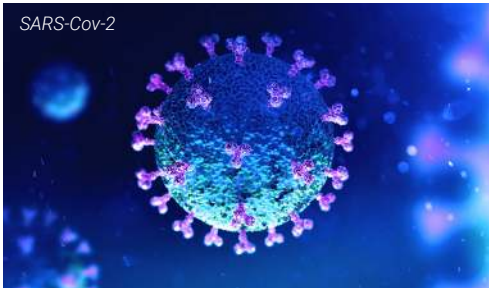

Shigella


Escherichia Coli


Campylobacter spp


Streptococcus pneumoniae


Acinetobacter baumannii


SARS-Cov-2


Pseudomonas aeruginosa


Haemophilus influenzae


Salmonella

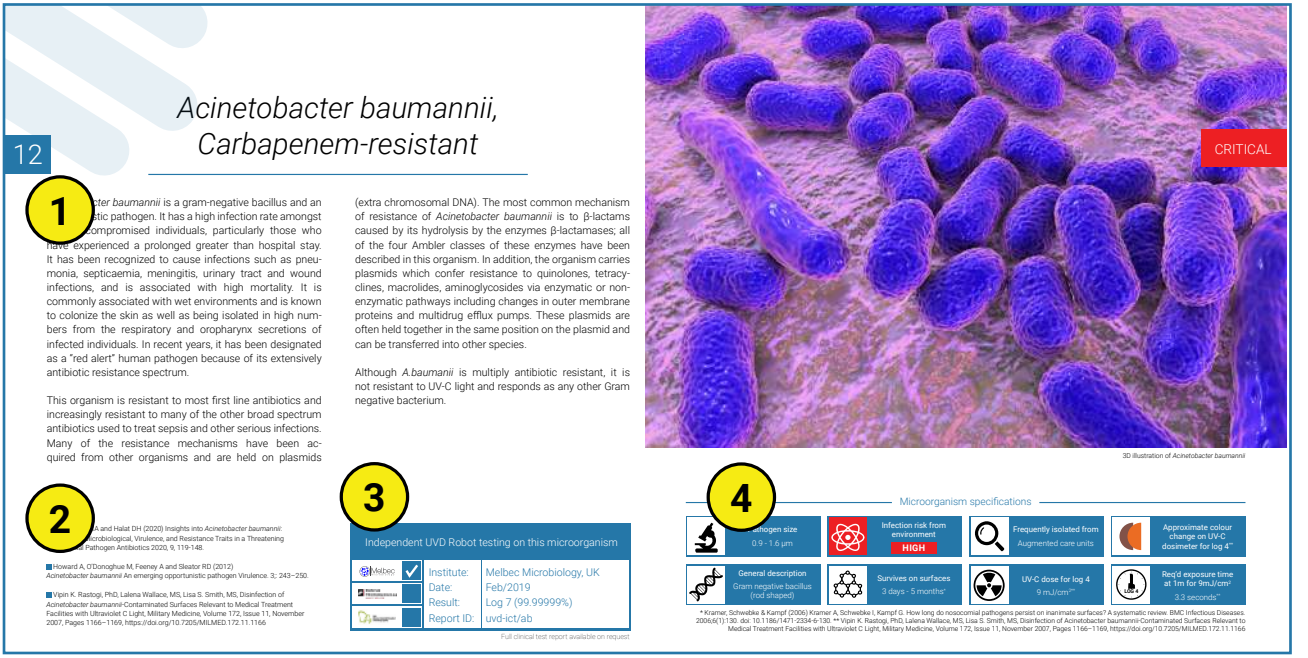

Klebsiella pneumoniae


Staphylococcus aureus


Enterococcus faecium


Clostridium difficile spores

How to use this guide



12

Acinetobacter baumannii, Carbapenem-resistant

1

cter baumannii is a gram-negative bacillus and an tic pathogen. It has a high infection rate amongst compromised individuals, particularly those who have experienced a prolonged greater than hospital stay. It has been recognized to cause infections such as pneumonia, septicaemia, meningitis, urinary tract and wound infections, and is associated with high mortality. It is commonly associated with wet environments and is known to colonize the skin as well as being isolated in high numbers from the respiratory and oropharynx secretions of infected individuals. In recent years, it has been designated as a "red alert" human pathogen because of its extensively antibiotic resistance spectrum.

This organism is resistant to most first line antibiotics and increasingly resistant to many of the other broad spectrum antibiotics used to treat sepsis and other serious infections. Many of the resistance mechanisms have been acquired from other organisms and are held on plasmids (extra chromosomal DNA). The most common mechanism of resistance of *Acinetobacter baumannii* is to β-lactams caused by its hydrolysis by the enzymes β-lactamases; all of the four Ambler classes of these enzymes have been described in this organism. In addition, the organism carries plasmids which confer resistance to quinolones, tetracyclines, macrolides, aminoglycosides via enzymatic or non-enzymatic pathways including changes in outer membrane proteins and multidrug efflux pumps. These plasmids are often held together in the same position on the plasmid and can be transferred into other species.

Although *A.baumanii* is multiply antibiotic resistant, it is not resistant to UV-C light and responds as any other Gram negative bacterium.

CRITICAL

3D illustration of *Acinetobacter baumannii*

2

A and Halat DH (2020) Insights into *Acinetobacter baumannii*: crobiological, Virulence, and Resistance Traits in a Threatening Pathogen Antibiotics 2020, 9, 119-148.

Howard A, O'Donoghue M, Feeney A and Sleator RD (2012) *Acinetobacter baumannii* An emerging opportunistic pathogen Virulence. 3; 243–250.

Vipin K. Rastogi, PhD, Lalena Wallace, MS, Lisa S. Smith, MS, Disinfection of *Acinetobacter baumannii*-Contaminated Surfaces Relevant to Medical Treatment Facilities with Ultraviolet C Light, Military Medicine, Volume 172, Issue 11, November 2007, Pages 1166–1169, https://doi.org/10.7205/MILMED.172.11.1166

3

Independent UVD Robot testing on this microorganism

Institute:	Melbec Microbiology, UK
Date:	Feb/2019
Result:	Log 7 (99.99999%)
Report ID:	uvd-ict/ab

Full clinical test report available on request

4

Microorganism specifications

ogen size 0.9 - 1.6 µm	Infection risk from environment HIGH	Frequently isolated from Augmented care units	Approximate colour change on UV-C dosimeter for log 4**
General description Gram negative bacillus (rod shaped)	Survives on surfaces 3 days - 5 months*	UV-C dose for log 4 9 mJ/cm²**	Req'd exposure time at 1m for 9mJ/cm² 3.3 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** Vipin K. Rastogi, PhD, Lalena Wallace, MS, Lisa S. Smith, MS, Disinfection of *Acinetobacter baumannii*-Contaminated Surfaces Relevant to Medical Treatment Facilities with Ultraviolet C Light, Military Medicine, Volume 172, Issue 11, November 2007, Pages 1166–1169, https://doi.org/10.7205/MILMED.172.11.1166

1 Background information about the pathogen written by Professor Val Edwards-Jones - PhD, CSci, FIBMS.

2 A list of references used in the background text.

3 Details of independent clinical studies to confirm the efficacy of UVD Robots against this pathogen.

4 Pathogen specifications:

Pathogen size: An indication of the microorganism's physical dimensions stated in either µm (micron) or nm (nanometer).

General description: Refers to the shape and type of the microorganism.

Infection risk from environment: A rating by Prof. Val Edwards-Jones regarding the risk this pathogen from the environtment.
There are three classifications: HIGH MEDIUM LOW

Survival time on surfaces: Based on third party data, a survival time window for this pathogen on typical healthcare surfaces.

Frequently isolated from: Highlights the healthcare areas where this pathogen is most frequently found.

UV-C dose for log 3/4: Based on third party data, the **approximate** UV-C dose necessary to achieve the corresponding log reduction.

UVC

Approximate colour change on UV-C dosimeter for log 3/4: A representation of the colour change required on the dosimeter to achieve the corresponding log reduction.
There are four classifications for each type:

LOG 4

Req'd exposure time at 1m for XXmJ/cm²: Number of seconds the UVD Robot requires to deliver the corresponding dosage onto any given surface at a distance of 1 meter.

Acinetobacter baumannii, Carbapenem-resistant

Acinetobacter baumannii is a gram-negative bacillus and an opportunistic pathogen. It has a high infection rate amongst immunocompromised individuals, particularly those who have experienced a prolonged greater than hospital stay. It has been recognized to cause infections such as pneumonia, septicaemia, meningitis, urinary tract and wound infections, and is associated with high mortality. It is commonly associated with wet environments and is known to colonize the skin as well as being isolated in high numbers from the respiratory and oropharynx secretions of infected individuals. In recent years, it has been designated as a "red alert" human pathogen because of its extensively antibiotic resistance spectrum.

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- Moubareck CA and Halat DH (2020) Insights into *Acinetobacter baumannii*: A Review of Microbiological, Virulence, and Resistance Traits in a Threatening Nosocomial Pathogen Antibiotics 2020, 9, 119-148.
- Howard A, O'Donoghue M, Feeney A and Sleator RD (2012) *Acinetobacter baumannii* An emerging opportunistic pathogen Virulence. 3;: 243–250.
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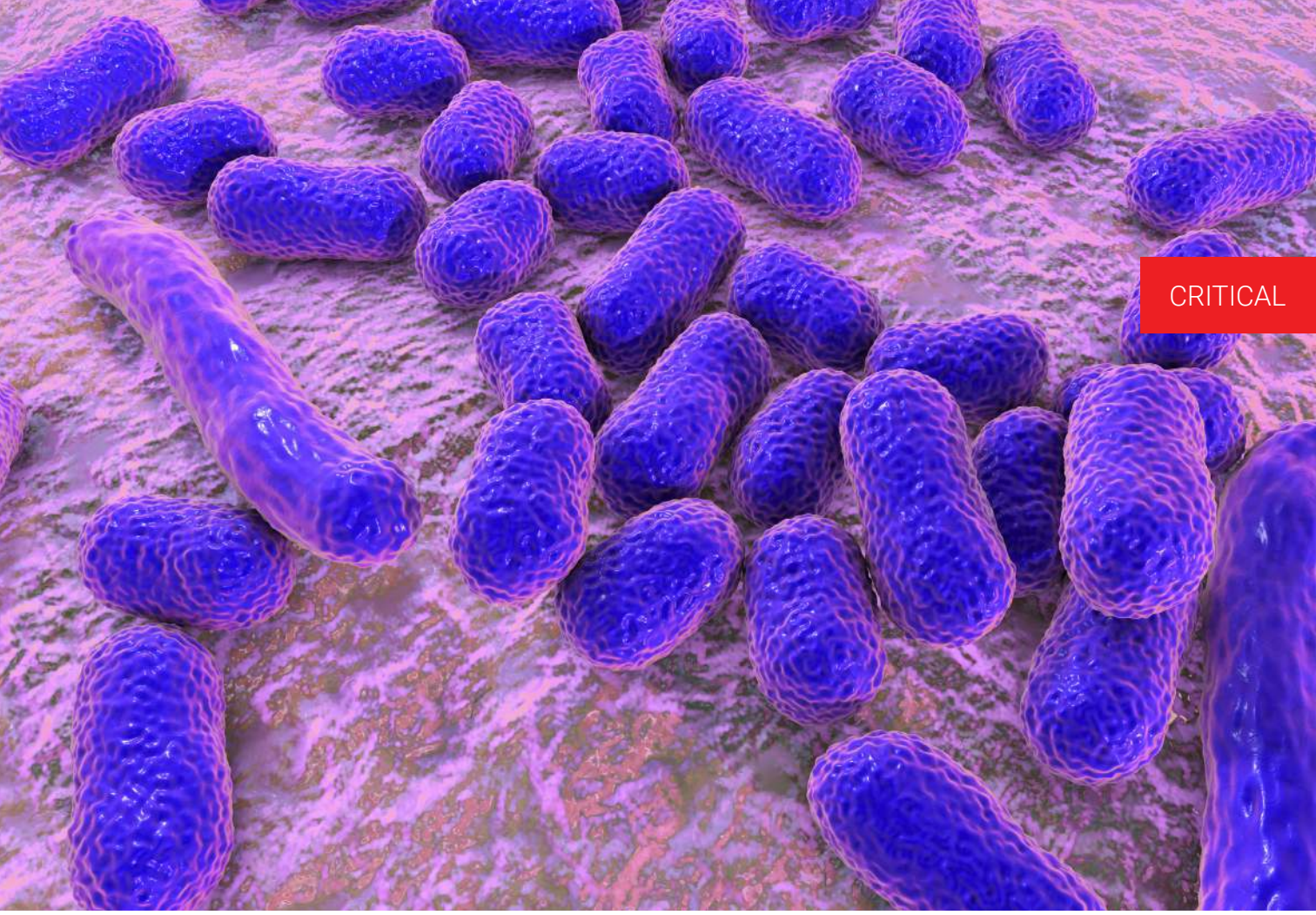
Independent UVD Robot testing on this microorganism

Melbec Microbiology ✓	Institute:	Melbec Microbiology, UK
Danish Technological Institute	Date:	Feb/2019
	Result:	Log 7 (99.99999%)
	Report ID:	uvd-ict/ab

Full clinical test report available on request



3D illustration of *Acinetobacter baumannii*

Microorganism specifications

Pathogen size
0.9 - 1.6 µm

Infection risk from environment
HIGH

Frequently isolated from
Augmented care units

Approximate colour change on UV-C dosimeter for log 4**

General description
Gram negative bacillus (rod shaped)

Survives on surfaces
3 days - 5 months*

UV-C dose for log 4
9 mJ/cm²**

Req'd exposure time at 1m for 9mJ/cm²
3.3 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** Vipin K. Rastogi, PhD, Lalena Wallace, MS, Lisa S. Smith, MS, Disinfection of Acinetobacter baumannii-Contaminated Surfaces Relevant to Medical Treatment Facilities with Ultraviolet C Light, Military Medicine, Volume 172, Issue 11, November 2007, Pages 1166–1169, https://doi.org/10.7205/MILMED.172.11.1166

Pseudomonas aeruginosa, carbapenem-resistant

Pseudomonas infection is caused by strains of bacteria found widely in the environment such in soil and water; the most common type causing infections in humans is called *Pseudomonas aeruginosa*. This is an opportunistic pathogen that causes infections in the blood, lungs (pneumonia), or other parts of the body after surgery, causing an estimated 51,000 healthcare-associated infections (HAI) in the United States annually. Those most at risk of acquiring *P. aeruginosa* infections are those on ventilators, have catheters *in situ* or those with burns or surgical wounds.

P. aeruginosa infections are associated with high morbidity and mortality rates especially in hospitalized patients with weakened immune systems, because it is very difficult to treat. Recent research on bloodstream infections showed that patients with a Pseudomonas infection had a higher mortality rate than patients with infections caused by other Gram-negative bacilli. *P. aeruginosa* is often difficult to treat because of its intrinsic (natural) resistance to many commonly used antimicrobial drugs; ≈13% of isolates causing HAI are multidrug resistant (MDR). Therefore carbapenems have become important antimicrobial drugs for clinical management of serious *P. aeruginosa* infections. However, there are more strains carrying carbapenemases (see *Enterobacteriacae* for description of carbepenemases).

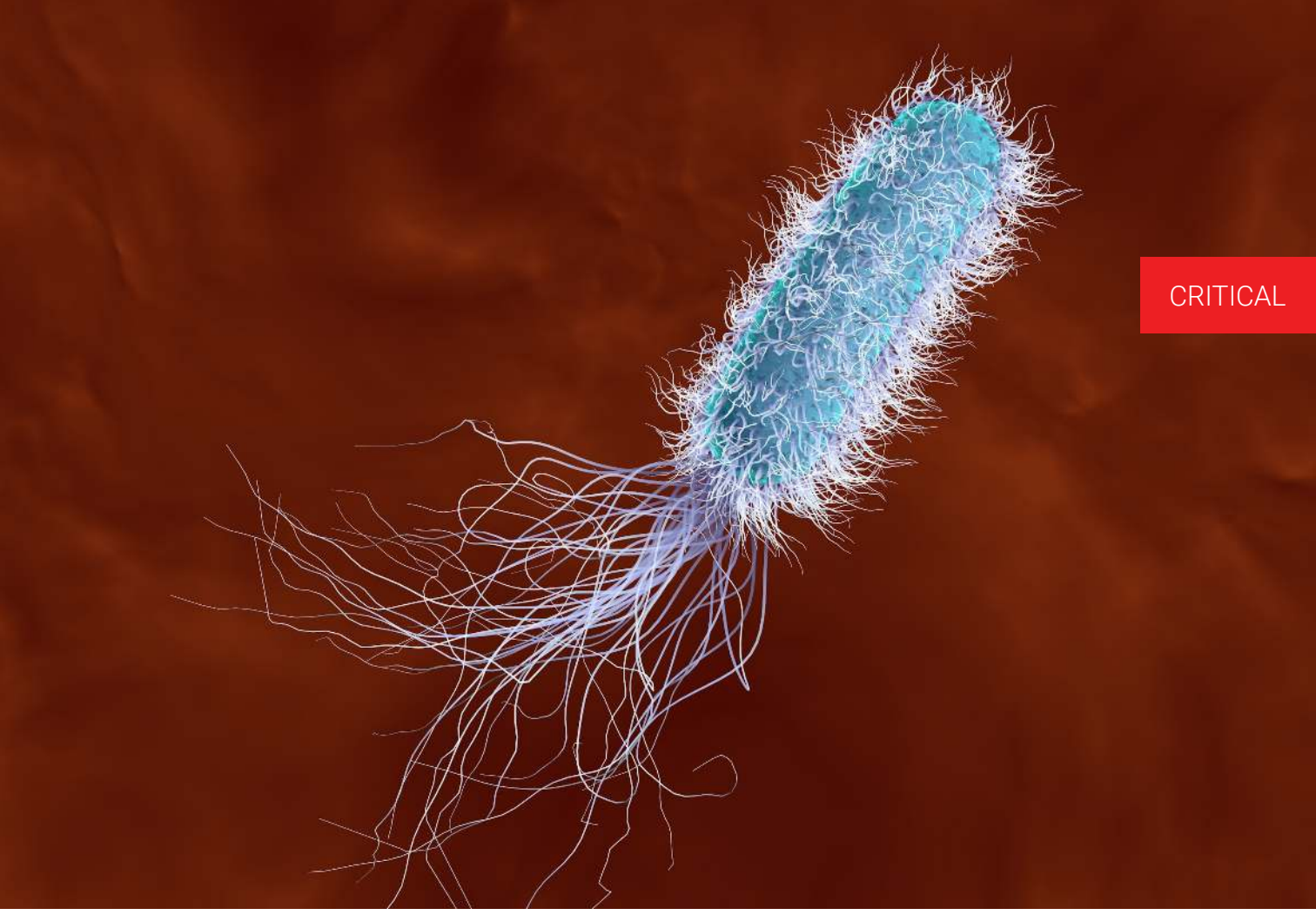
P. aeruginosa is notorious for causing water related problems in health care settings and is highlighted as a problematic organism because of its ability to form biofilm (A biofilm is a surface bound community of organisms residing within a polymeric matrix). This makes the organism in the environment very difficult to kill with antiseptics because many of them are unable to penetrate the biofilm. In a study using silicone and Teflon tubing, biofilm was eradicated using UV-C. 10cm Teflon and silicone tubes and 20 cm Teflon tubes were contaminated with *P. aeruginosa* and biofilms allowed to form. The tubes were sampled from the total inner surface of the tubes and a reduction in colony counts were between 96-100%. Colony counts on the control samples were between 10^5–10^9 CFU ml−1. The applied UV-C doses were between 15 and 300 min. Disinfection (100%) was obtained in 10 cm Teflon tubes exposed for 30 min and a 20 cm Teflon tube exposed for 300 min. The disinfection rate was 96% for the 20 cm tube if the dose was reduced to 30 min. Differences between the tubes were dependent on the differences in length and the type of material. The UV-C light was transmitted six times more efficiently in Teflon than in silicone tubes of equal length (10 cm). The germicidal effect to obtain a 99.99% killing rate for the biofilm (~78 J m−2) is comparable to that for the planktonic bacterium.

Jimmy Bak, Søren D. Ladefoged, Michael Tvede, Tanja Begovic & Annette Gregersen (2010) Disinfection of *Pseudomonas aeruginosa* biofilm contaminated tube lumens with ultraviolet C light emitting diodes, Biofouling, 26:1, 31-38

Independent UVD Robot testing on this microorganism

Melbec	Institute:	Danish Technological Institute
Danish Technological Institute ✓	Date:	Jun/2017
	Result:	Log 5.73 (99.99973%)
	Report ID:	uvd-ict/pa

Full clinical test report available on request



CRITICAL

3D illustration of *Pseudomonas aeruginosa*

Microorganism specifications

Pathogen size
1-5 µm long
0.5-1.6-1 µm

Infection risk from environment
HIGH

Frequently isolated from
Augmented care units

Approximate colour change on UV-C dosimeter for log 4**

General description
Gram negative bacillus (rod shaped)

Survives on surfaces
6 hours - 16 months
On dry floor: 5 weeks*

UV-C dose for log 4
25 mJ/cm²**

Req'd exposure time at 1m for 25 mJ/cm²
9.3 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** Light Sources Inc. 2014 (data provided was for a log 1 and log 2 reduction. Log 4 calculated based on the correlation between the log 1 and log 2 dosage)

Enterobacteriaceae, carbapenem-resistant ESBL-producing

Enterobacteriaceae are a large family of Gram negative bacteria that have over 30 different genera and 100 species. They commonly cause respiratory and urinary infections, both in healthcare settings and communities. Common examples include *Escherichia coli* and *Klebsiella pneumoniae*. These infections are usually treated with beta-lactam antibiotics (e.g. penicillins and cephalosporins) but many have become resistant because of enzymes called extended spectrum beta lactamases (ESBLs). These break the bonds in the beta-lactam antibiotic before it can have an effect. Infections, caused by ESBL-producing bacteria require more complex treatments. Instead of taking oral antibiotics at home, patients with these infections might require hospitalisation and intravenous (IV) carbapenem antibiotics. In 2017, there were an estimated 197,400 cases of ESBL-producing *Enterobacteriaceae* among hospitalized patients and 9,100 estimated deaths in the United States [Source: 2019 AR Threats Report]. Carbapenems are one of the few remaining antibiotics that can treat ESBL related infections and these are becoming resistant too. When *Enterobacteriaceae* develop resistance to carbapenems, they are called carbapenem-resistant *Enterobacteriaceae* (CRE). Occasionally CRE are resistant to all available antibiotics and therefore are a huge threat to public health.

UNDERSTANDING THE DIFFERENCE BETWEEN CRE AND CP-CRE?

There are many different mechanisms that can result in carbapenem resistance. Some strains produce carbapenemases, (enzymes that break down carbapenems) making them ineffective, are called carbapenemase-producing CRE (CP-CRE). CP-CRE are a subset of all CRE.

Duin D and Doi Y. The global epidemiology of carbapenemase-producing *Enterobacteriaceae* Virulence. 2017; 8(4): 460–469.

There are four classes of β-lactamases defined by the Ambler classification system, and carbapenemases belong to three of them:

- Class A (K. pneumoniae carbapenemases, (KPC)),
- Class B (metallo-β-lactamases (MBL), New Delhi metallo-β-lactamases, NDM)
- Class D (OXA-48-like carbapenemases)

KPC are the most commonly occurring CPE in the United States. MBL-producing CPE have been most commonly associated with the Indian subcontinent as well as with specific countries in Europe, including Romania, Denmark, Spain, and Hungary. The epi-centre of OXA-48-like-producing is in Turkey and surrounding countries.

Detailed knowledge of the epidemiology and molecular characteristics of CPE is essential to stem the spread of these pathogens. In the United States, CRE are generally associated with healthcare settings, and approximately 30% carry a carbapenemase. The carbapenemase genes are found on mobile genetic elements, which can be easily shared between bacteria. Preventing the spread of these resistant bacteria is critical to reduce ongoing resistance against newer antibiotics. Recommended therapy for these infections is combination therapy ceftazidime-avibactam + aztreonam.

Although these organisms are difficult to treat with antibiotics they are rapidly killed with UV-C in minutes.

Independent UVD Robot testing on this microorganism

Melbec	Institute:	Melbec Microbiology, UK
Danish Technological Institute	Date:	Feb/2019, Sep/2019, Feb/2020
	Result:	Log 6, Log 3.55, Log 3.16
	Report ID:	uvd-ict/kp

Full clinical test report available on request

3D illustration of *Enterobacteriaceae*

Microorganism specifications

Pathogen size 2 µm x 0.5 µm	**Infection risk from environment** **HIGH**	Frequently isolated from High touch areas and bathrooms	**Approximate colour change on UV-C dosimeter for log 4****
General description Gram negative bacillus (rod shaped)	**Survives on surfaces** 2 hours - >30 months*	**UV-C dose for log 4** 20 mJ/cm²**	**Req'd exposure time at 1m for 20 mJ/cm²** 7.4 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** Giese N and Darby J. Water Research, V34, 2000.4007-4013 (data based on Klebsiella pneunomiae).

Enterococcus faecium, vancomycin-resistant

Enterococci are bacteria normally present in human intestines and in the female genital tract. They are often found in the environment, such in soil and water and cause a variety of healthcare associated infection, including urinary tract infections and sepsis. They often respond to the broad spectrum antibiotic ampicillin, but have become more antibiotic resistant over the last decades. The drug of choice now for their treatment is another antibiotic affecting the cell wall, Vancomycin. Over the last 20 years, there have been an increasing number of strains shown to be resistant to this drug of choice and they have developed this resistance through acquisition of the gene vanA or VanB. Vancomycin resistant enterococci (VRE) are now commonplace within healthcare settings. *Enterococcus faecium* and *Enterococcus faecalis* cause the majority of enterococcal infections.

In 2017, VRE caused an estimated 54,500 infections among hospitalized patients and 5,400 estimated deaths in the United States [Source: 2019 AR Threats Report]. A number of patients are at risk of contracting this infection including:

- Those who have been previously treated with antibiotics, including vancomycin, for long periods of time.
- People who are hospitalized, have undergone surgical procedures, or have medical devices inserted in their bodies (such as catheters)
- People with weakened immune systems, patients in intensive care units, or in cancer or transplant wards.

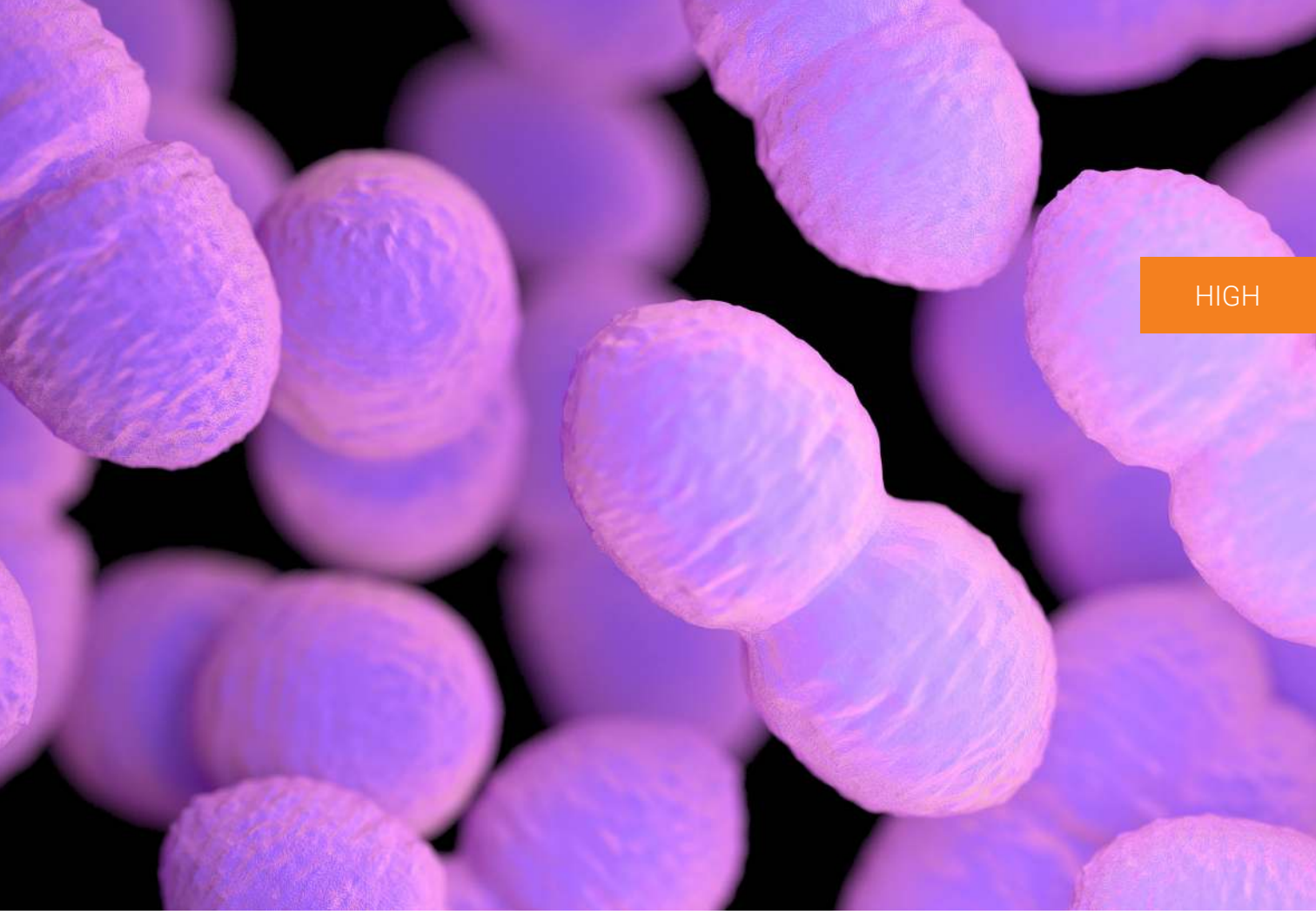
VRE can spread from one person to another through contact with contaminated surfaces or equipment or through person to person spread, often via contaminated hands, so disinfection of the patient environment is very important. It is not spread through the air by coughing or sneezing.

In solid organ transplant units, one type of VRE-*Enterococcus faecium* is the most common cause of central line-associated bloodstream infections (CLABSIs), according to CDC's National Healthcare Safety Network. More than 70% of these *E. faecium* are resistant to vancomycin, a mainstay for treating these infections. This makes healthcare providers reliant on other antibiotics. Maintaining and improving infection prevention and control interventions, such as hand hygiene and surface disinfection, is critical to further reduce the number of VRE infections and protect vulnerable patient populations.

Independent UVD Robot testing on this microorganism

Melbec	Institute:	Danish Technological institute
DANISH TECHNOLOGICAL INSTITUTE ✓	Date:	June/2017
	Result:	Log 7 (99.99999%)
	Report ID:	uvd-ict/eh

Testing carried out on *Enterococcus hirae*.
Full clinical test report available on request



3D illustration of *Enterrococcus faecium*

Microorganism specifications

Pathogen size 0.6-2.0 µm x 0.6-2.5 µm	**Infection risk from environment** **HIGH**	**Frequently isolated from** High touch areas	**Approximate colour change on UV-C dosimeter for log 4****
General description Gram positive coccus	**Survives on surfaces** 5 days - 4 months*	**UV-C dose for log 4** No data available**	**Req'd exposure time at 1m for 50 mJ/cm²** 18.5 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** disclaimer: In the absence of third party data, based on the log 7 reduction achieved by the UVD Robot against Enterrococcus hirae at the Danish Techological Institute, the dosage of 50 mJ/cm^2 is deemed sufficient to achieve a log 4 reduction against this organism.

Staphylococcus aureus, methicillin-resistant vancomycin-intermediate & resistant

MRSA stands for methicillin-resistant *Staphylococcus aureus*, a type of bacteria that is resistant to several antibiotics. MRSA commonly causes skin infections (including surgical site infections), but can also cause pneumonia and sepsis. It can be carried on the skin without causing infection (asymptomatic carriage) so it is important to decontaminate the individual prior to surgery.

The risk of infection increases with activities or places that involve crowding, skin-to-skin contact, and shared equipment or supplies. Some of the people who carry MRSA can go on to get a MRSA infection. Non-intact skin, such as abrasions or incisions, is often the site of an MRSA infection. Contact with a contaminated wound or by sharing personal items, such as towels or razors, that have touched infected skin can also be a source of infection. Drug users are more likely to develop a serious staph infection.

The history of MRSA infection goes back to 1961 when it was first described. Since then, the incidence and prevalence of MRSA infection have been increasing dramatically across the United States. The reported incidence of MRSA infection ranges from 7% to 60% and approximately 5% of patients in U.S. hospitals carry MRSA in their nose or on their skin.

The commonly associated risk factors for MRSA infection are prolonged hospitalization, intensive care admission, recent hospitalization, recent antibiotic use, MRSA colonization, invasive procedures, HIV infection, admission to nursing homes, open wounds, haemodialysis, and discharge with long-term central venous access or long-term indwelling urinary catheter.

The key reason for MRSA resistance to beta-lactam antibiotics is due to the presence of the mecA gene sequence. Vancomycin and daptomycin are used to treat MRSA infection with teicoplanin and/or linezolid used when vancomycin is not tolerated.

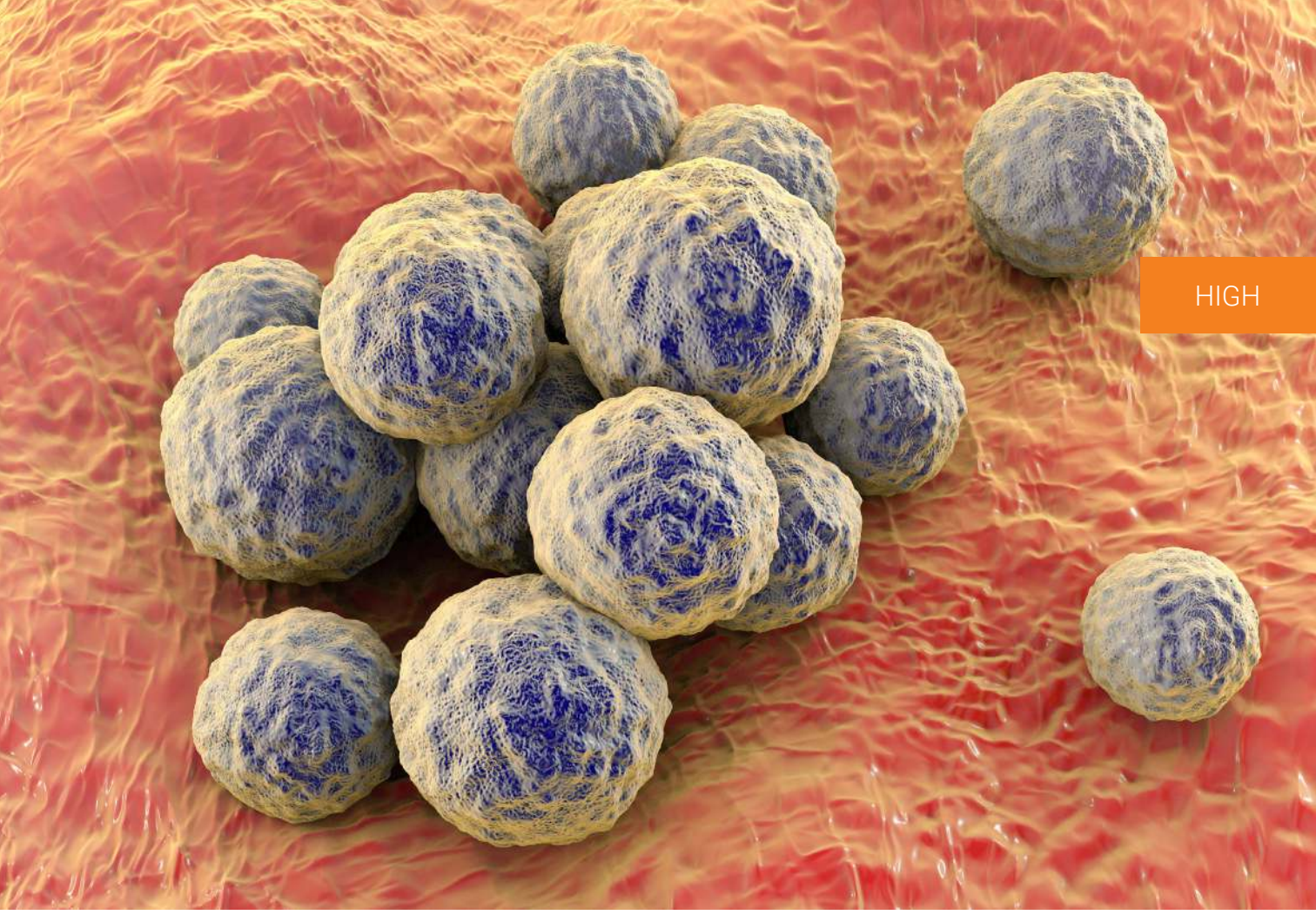
Prevention and control of MRSA infections include strict hand hygiene and adequate contact precautions including cohorting MRSA patients or isolation. The key to managing MRSA infections is to prevent them in the first place. Environmental measures like cleaning and disinfecting the room are important. UV-C has the potential to maintain good hygiene standards within the healthcare environment and minimise risks from acquisition of MRSA.

■ Abdul H. Siddiqui; Janak Koirala. Methicillin Resistant *Staphylococcus aureus* (MRSA). NCBI books last updated June 29, 2020. https://www.ncbi.nlm.nih.gov/books/NBK482221/

Independent UVD Robot testing on this microorganism

Melbec	Institute:	Danish Technological institute
DANISH TECHNOLOGICAL INSTITUTE ✓	Date:	June/2017
✓	Result:	Log 6.4 (99.99994%)
✓	Report ID:	uvd-ict/sa

Full clinical test report available on request



3D illustration of *Staphylococcus aureus*

Microorganism specifications

Pathogen size 1 µm in diameter	**Infection risk from environment** **HIGH**	**Frequently isolated from** Dust and high touch areas	**Approximate colour change on UV-C dosimeter for log 4****
General description Gram positive coccus	**Survives on surfaces** 7 days - 7 months*	**UV-C dose for log 4** 10.4 mJ/cm²**	**Req'd exposure time at 1m for 10.4 mJ/cm²** 3.9 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** Chang JC, et al. Appl Environ Microbiol 1985;49:1361-5.

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Helicobacter pylori, clarithromycin-resistant

Helicobacter pylori (*H. pylori*) is the only known pathogen that inhabits the gastric mucosa of almost half of the world's population and is known to cause chronic gastritis to duodenal ulceration and gastric adenocarcinoma. Prior to the identification of this organisms as the cause of gastritis and ulceration, numerous operations were performed to resolve the gastric ulcers. Nowadays, treatment with antibiotics is sufficient to resolve this condition.

In general, combined therapy is used to eradicate *H. pylori* infection, triple therapy, including two antibiotics, amoxicillin and clarithromycin, and a proton pump inhibitor given for a week has been recommended as the treatment of choice at several consensus conferences. However, the efficiency of this standard regimen has decreased over the past decades due to resistance developing to one of the antibiotics used, clarithromycin.

Other treatments have also been proposed, including metronidazole, as well as tetracycline, fluoroquinolones, and rifamycins for which resistance has become an emerging issue. Resistance of *H. pylori* to the limited range of antibiotics that have efficacy in its treatment can severely affect attempts to eradicate this bacteria.

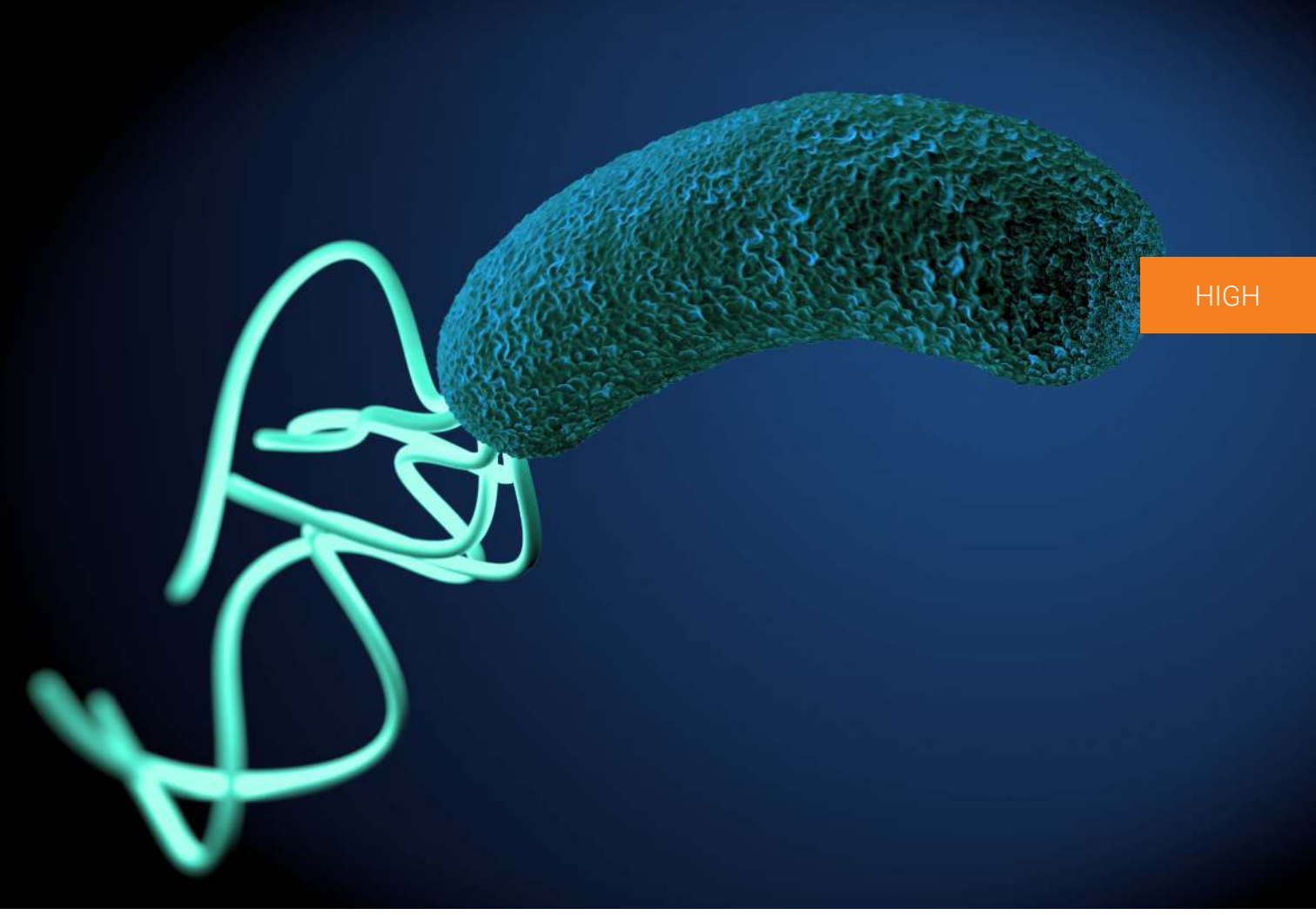
How *Helicobacter pylori* is spread is unknown and this leads to difficulties in eradicating the organism. The pathway of transmission and the reservoirs of this species have not been yet elucidated although it has been isolated from the gastrointestinal tract, including saliva and stools, suggesting that oral-oral and faecal-oral routes are the main transmission pathway. However, molecular analyses show that *Helicobacter pylori* is also present in various aquatic environments suggesting that human faecal contaminated water sources could be a plausible reservoir of the pathogen. In addition, zoonotic transmission by dogs, cats, sheep and flies as well as iatrogenic transmission by endoscopic procedures have been proposed.

The species has been detected in several water sources, including lakes, rivers, tap water, well water, irrigation water and sea water table but also has been detected in water distribution systems. Thus, drinking water could be the pathway for returning to humans, even though food and occasionally recreational waters may also participate in the *Helicobacter pylori* transmission cycle.

UV-C is used in treating contaminated water.

Kouitcheu Mabeku, L.B., Eyoum Bille, B., Tepap Zemnou, C. et al. Broad spectrum resistance in *Helicobacter pylori* isolated from gastric biopsies of patients with dyspepsia in Cameroon and efflux-mediated multiresistance detection in MDR isolates. BMC Infect Dis 19, 880 (2019).

Apolinaria García, María José Salas-Jara, Carolina Herrera, and Carlos González Biofilm and *Helicobacter pylori*: From environment to human host World J Gastroenterol. 2014 May 21; 20(19): 5632–5638.



3D illustration of *Helicobacter pylori*

Microorganism specifications

Pathogen size
2-4 µm x 0.5-1.0 µm

Infection risk from environment
LOW

Frequently isolated from
Not commonly found in the environment

Dosimeter reference n/a because infection risk from environment is low

General description
Gram negative spiral shaped bacterium

Survives on surfaces
≤90 minutes*

UV-C dose for log 4
Not applicable**

Req'd exposure time at 1m for XXmJ/cm²
LOG 4
Not applicable**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** disclaimer: based on a low infection risk from the environtment. No value provided.

Campylobacter spp., fluoroquinolone-resistant

Campylobacter cause diarrhoea (often bloody), fever, abdominal cramps, and sometimes complications such as irritable bowel syndrome, temporary paralysis, and arthritis. *Campylobacter* causes an estimated 1.5 million infections and $270 million in direct medical costs every year.

Of those infections, 29% have decreased susceptibility to fluoroquinolones (e.g., ciprofloxacin) or macrolides (e.g., azithromycin), the antibiotics used to treat severe *Campylobacter* infections.

Campylobacter spreads to people through raw or undercooked chicken, unpasteurized milk, contaminated food and water, and through direct contact with animals.

Campylobacter infections with decreased susceptibility are more common in low- and middle-income countries, putting travellers at risk for infections that may be harder to treat.

https://www.cdc.gov/drugresistance/pdf/threats-report/campylobacter-508.pdf

An outbreak of multidrug-resistant *Campylobacter* infections linked to pet store puppies occurred recently and only one antibiotic was able to treat his resistant infection.

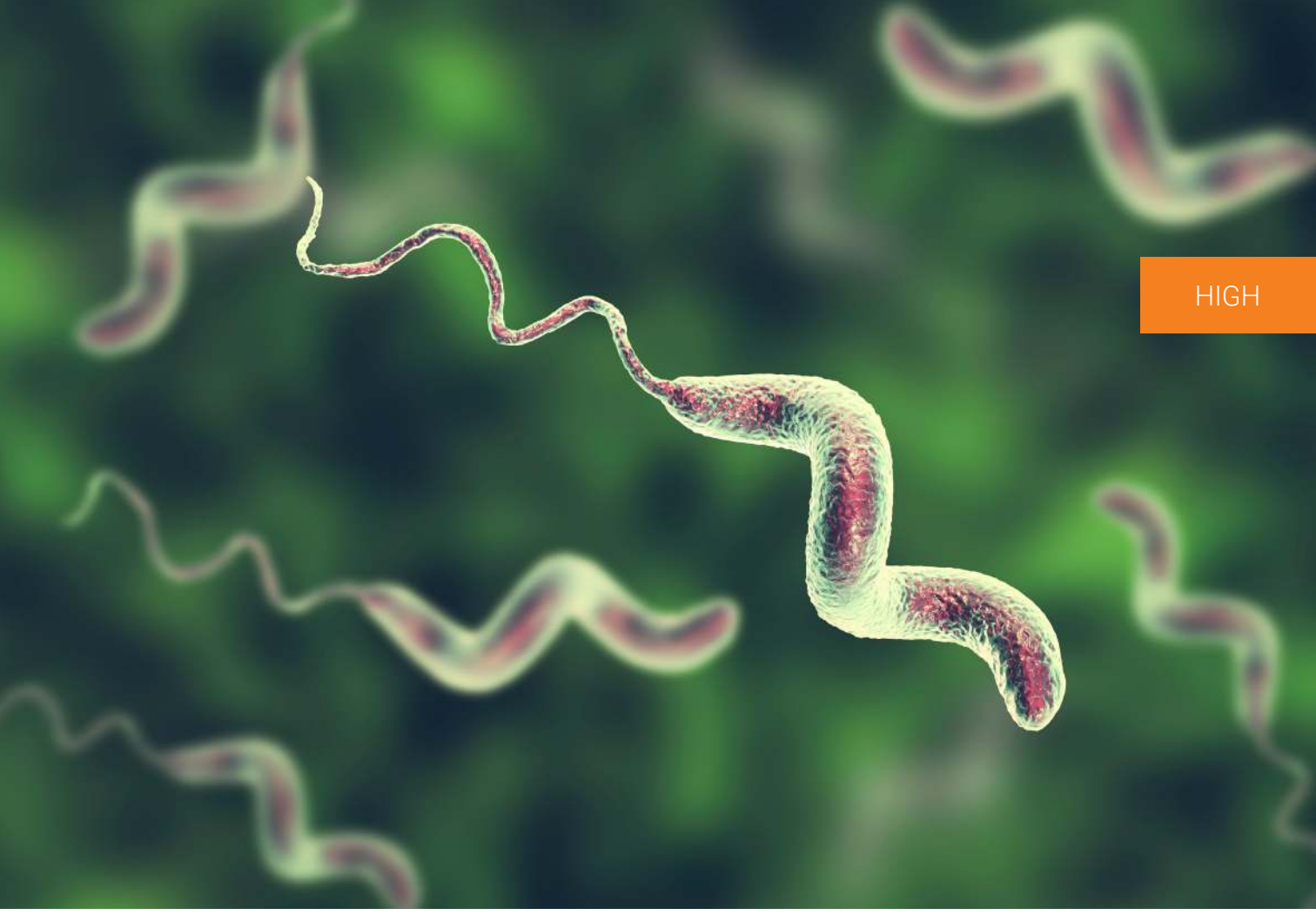
It is estimated that 50 billion chickens are slaughtered for food each year and their cultivation and processing can be a huge problem in terms of infection.

It is well known that the flocks are often highly contaminated with *Campylobacter* and the environment is very difficult to keep clean for new birds and during processing. UV-C could reduce environmental contamination and perhaps transmission to the birds when the barns are emptied, prior to repopulation.

Campylobacter is a gram-negative curved bacillus and should be reduced in numbers by UV-C in a similar time frame to *E.coli*.

	Percentage of Campylobacter	Estimated numbers of infections pr. year	Estimated infections pr. 100.000 U.S pupolation
Decreased susceptibility to ciprofloxacin	28%	429.600	130
Decreased susceptibility to azithromycin	4%	55.600	20
Decreased susceptibility to ciprofloxacin or azithromycin	29%	448.400	140
Decreased susceptibility to ciprofloxacin or azithromycin	2%	36.800	10

Antibiotic susceptibility helps describe how sensitive germs are to particular antibiotics. An antibiotic can stop the growth of or kille a susceptible germ.
* Average (2015-2017), includes *Campylobacter jejuni* and *Campolybacter coli*



3D illustration of *Campylobacter ssp*

Microorganism specifications

Pathogen size
0.2 - 0.5 µm x 0.5 - 5 µm

Infection risk from environment
MEDIUM

Frequently isolated from
Not commonly found in healthcare environments

Approximate colour change on UV-C dosimeter for log 4**

General description
Gram negative curved bacillus

Survives on surfaces
Up to 6 days*

UV-C dose for log 4
4.6 mJ/cm²**

Req'd exposure time at 1m for 4.6 mJ/cm²
1.7 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** Wilson BR, et al. Water Quality Technology Conference, Nov 15–19, 1992, Toronto, Canada, pp. 219–235, Amer. Wat. Works Assoc., Denver, CO. (The source referenced provides a dosage for Campylobacter jejuni)

Salmonella, fluoroquinolone-resistant

Non-typhoidal *Salmonella* causes an estimated 1.35 million infections, 26,500 hospitalizations, and 420 deaths each year in the United States, resulting in an estimated $400 million in direct medical costs.

People can get *Salmonella* from eating contaminated food products or from contact with faeces from infected people or animals (including touching animals or their surroundings). Antibiotics such as ciprofloxacin, azithromycin, and ceftriaxone are sometimes needed to treat patients with severe *Salmonella* infections. Resistant *Salmonella* infections can be more severe and have higher hospitalization rates.

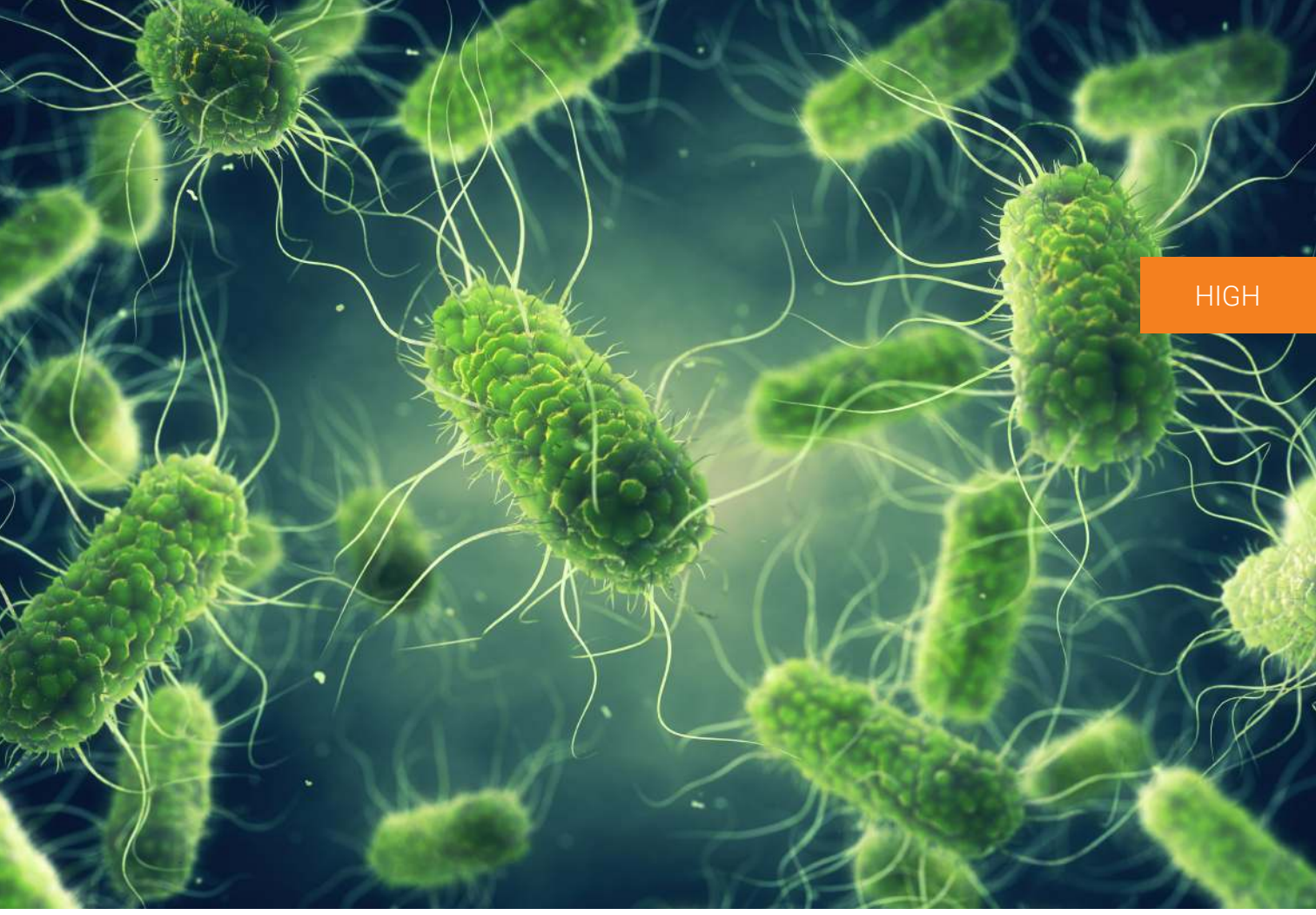
In 2014, the U.S. Food and Drug Administration (FDA) during routine monitoring, identified a multidrug-resistant strain of non typhoidal *Salmonella* serotype Infantis and subsequently identified this strain among ill people returning from travel to South America. This resistant strain spread rapidly and in 2018, it accounted for 25% of *Salmonella* Infantis infections. Most of these infected people contracted this strain and other types of resistant *Salmonella* linked to foodborne illness from chicken, pork, turkey, and beef, leaves healthcare providers with few options to treat patients with severe infections. This is a worrying problem as antibiotics are used to treat these severe infections, especially if sepsis results.

Salmonella bacteria love wet environments shielded from the sun. They have the remarkable ability to survive under adverse conditions. They survive between the pH's of four to eight plus, and can grow between eight and 45°C. *Salmonella* can survive under low oxygen tension such as in manure slurry pits. They can survive for long periods in soil and in water and *Salmonella* spread onto fields in the form of manure may survive for long periods. It is best to spread the manure onto flat land where it is exposed to the drying effects of wind, and to the bactericidal effect of UV irradiation from the sun.

Manure should be spread onto cropland rather than onto pastures for grazing. *Salmonella* are no more or less sensitive to the effects of commonly used disinfectants than are other faecal bacteria. Chlorine solutions, iodines, quaternary ammoniums, phenolics, etc., are very good at killing *Salmonella* on surfaces however, efficient scraping/dry cleaning is important to get rid of organic matter and bedding, followed by wet cleaning with high pressure hot water/steam and then disinfection.

The use of UV-C in animal husbandry and also meat production may reduce the numbers of *Salmonella* infections globally.

https://www.cdc.gov/drugresistance/pdf/threats-report/nt-*Salmonella*-508.pdf



3D illustration of *Salmonella*

Microorganism specifications

Pathogen size 1 x 2 µm	**Infection risk from environment** MEDIUM	**Frequently isolated from** Not commonly found in healthcare environments	**Approximate colour change on UV-C dosimeter for log 4****
General description Gram negative bacillus (rod shaped)	**Survives on surfaces** 1 day*	**UV-C dose for log 4** 7 mJ/cm²**	**Req'd exposure time at 1m for 7 mJ/cm²** 2.6 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** Tosa, K. and Hirata, T. IAWQ 19th Biennial International Conference, 1998. Vol. 10, Health- Related Water Microbiology.

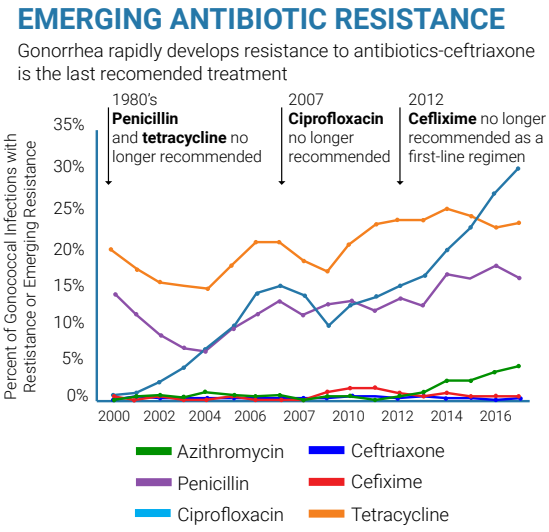
Neisseria gonorrhoeae, cephalosporin-resistant, fluoroquinolone-resistant

Gonorrhoea is a sexually transmitted disease (STD) that can infect both men and women. It can cause infections in the genitals, rectum, and throat. It is a very common infection, especially among young people ages 15-24 years.

Symptoms vary but if left untreated but can cause long term complications include arthritis, pelvic inflammatory disease, epididymitis and long term, infertility.

Treatment of gonorrhoea until recently has been relatively straightforward using penicillin or clarithromycin, however, they have acquired resistance and now drug resistant strains are increasing in prevalence.

Neisseria gonorrhoeae is a strictly human disease, transmitted during sexual intercourse, and is not found in the environment. However, UV-C may have an application in decontamination of medical instruments and associated procedures.



https://www.cdc.gov/std/gonorrhea/arg/basic.htm

3D illustration of *Neisseria gonorrhoeae*

Microorganism specifications

Pathogen size
0.6 - 1 µm in diameter

Infection risk from environment
LOW

Frequently isolated from
Not found in the environment

Dosimeter reference n/a because infection risk from environment is low

General description
Gram negative diplococcus

Survives on surfaces
1-3 days*

UV-C dose for log 4
Not applicable**

Req'd exposure time at 1m for XXmJ/cm²
Not applicable**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** disclaimer: based on a low infection risk from the environtment. No value provided.

Streptococcus pneumoniae, penicillin-non-susceptible

Streptococcus pneumoniae (pneumococcus) is a leading cause of bacterial pneumonia and meningitis in the United States. It also is a common cause of bloodstream infections, and ear and sinus infections. There are more than two million pneumococcal infections each year in the United States, resulting in more than 6,000 deaths and $4 billion in total costs. In more than 30% of infections, the bacteria are resistant to one or more clinically relevant antibiotics.

Drug-resistant *S. pneumoniae* has an effective vaccine to prevent infections, called pneumococcal conjugate vaccine (PCV), but currently is only offered to vulnerable groups, including the over 65 years.

It has also decreased the spread of resistant *Streptococcus pneumoniae* strains, because vaccinated people do not spread the bacteria. Blocking the spread reduces resistant infections among children, as well as adults, through vaccine indirect effects (or "herd immunity").

S. pneumoniae is a capsulate organism and an exclusive human pathogen and does not persist in the environment.

3D illustration of *Streptococcus pneumoniae*

Microorganism specifications

Pathogen size
0.5 - 1.25 µm in diameter

Infection risk from environment
MEDIUM

Frequently isolated from
Respiratory secretions

Approximate colour change on UV-C dosimeter for log 4**

General description
Gram positive diplococcus

Survives on surfaces
1 day - 20 days*

UV-C dose for log 4
9 mJ/cm²**

Req'd exposure time at 1m for 9 mJ/cm²
3.3 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** Harris, G.D, et al. Wat. Res.1987;21(6):687-692. (The source referenced provides a dosage for Streptococcus faecalis)

Haemophilus influenzae, ampicillin-resistant

Haemophilus influenzae is a commensal bacteria colonising the upper respiratory tract that can cause severe invasive infections such as meningitis and septicaemia. *H. influenzae* (non-typable) is considered a priority pathogen by WHO. It has been the most prevalent cause of community-acquired pneumonia and exacerbation of chronic obstructive pulmonary disease.

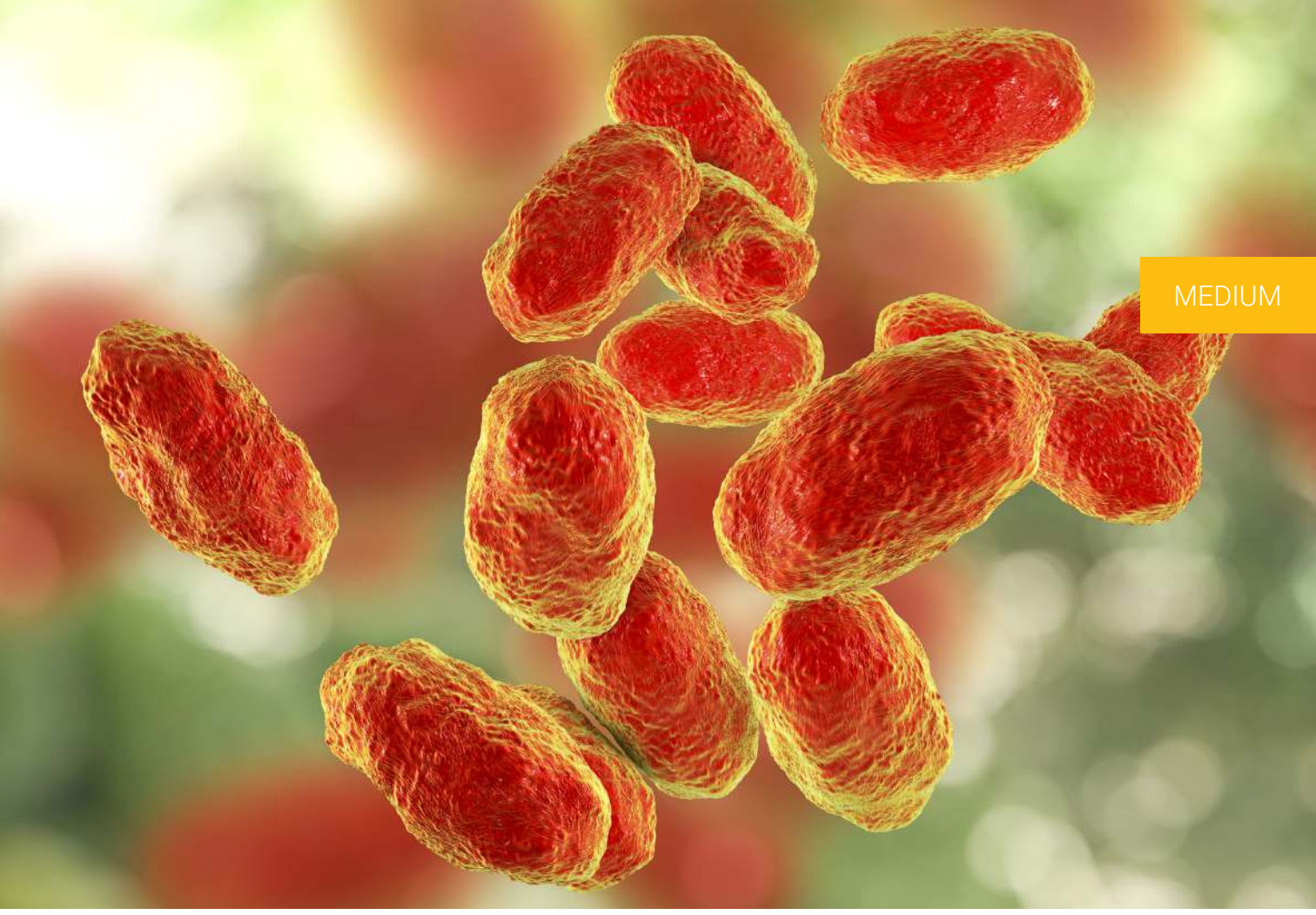
β-lactam antibiotics are the first choice of *H.influenzae* treatment. Ampicillin resistance of *H.influenzae* occurs because of two mechanisms of action. Strains that are resistant to ampicillin due to producing β-lactamase are termed β-lactamase positive, ampicillin resistant (BLPAR). Strains which do not produce β-lactamase but are resistant or intermediate to ampicillin are termed β-lactamase negative, ampicillin resistant (BLNAR) or β-lactamase negative, ampicillin intermediate (BLNAI). It also useful to understand the spread of drug-resistant genes.

This is a common respiratory infection in the young and elderly. In 1992, a vaccine against *H. influenzae* type B (based on the capsule), called the Hib vaccine was introduced in the UK. Since then, the incidence of childhood pneumonia and respiratory tract infections fell, and *H. influenzae* was almost eradicated in countries that adopted a vaccination programme. The vaccine has been a great success, but as vaccine uptake has increased, and rates of *H. influenzae* type B infection has fallen. However, infections of a different type of *H. influenzae* are increasing. Non-typeable *H. influenzae* (NTHi) cannot be protected by the Hib vaccine due to the lack of a bacterial capsule, and cases of NTHi infection have been rapidly increasing since 2011. There are reports of *H. influenzae* isolates even being resistant to Carbapenems, one of the last lines of defence against bacterial infections. This antibiotic is reserved for use only against multi-drug resistant bacterial infections. With the lack of an effective vaccine and rising resistance to the available treatment options, there is a chance that *Haemophilus influenzae* could return as a major cause of childhood mortality.

Haemophilus influenzae is a Gram-negative cocco-bacillus and people spread *H. influenzae*, including Hib, to others through respiratory droplets contaminating the air and surfaces in an area, especially in healthcare environments.

UV-C could be used to decontaminate paediatric areas housing the elderly with COPD, where transmission of droplets could be a possible source of infection

Yamada S, Seyama S, Wajima T, Yuzawa Y, Saito M, Tanaka E, Noguchi N. β-Lactamase-non-producing ampicillin-resistant *Haemophilus influenzae* is acquiring multi-drug resistance Journal of Infection and Public Health 2020, 13; 497-501.



3D illustration of *Haemophilus influenzae*

Microorganism specifications

Pathogen size 1 µm X 0.3 µm	**Infection risk from environment** MEDIUM	**Frequently isolated from** Respiratory secretions	**Approximate colour change on UV-C dosimeter for log 4****
General description Gram negative cocco-bacillus	**Survives on surfaces** 12 days*	**UV-C dose for log 4** No data available**	**Req'd exposure time at 1m for 50mJ/cm²** 18.5 seconds**

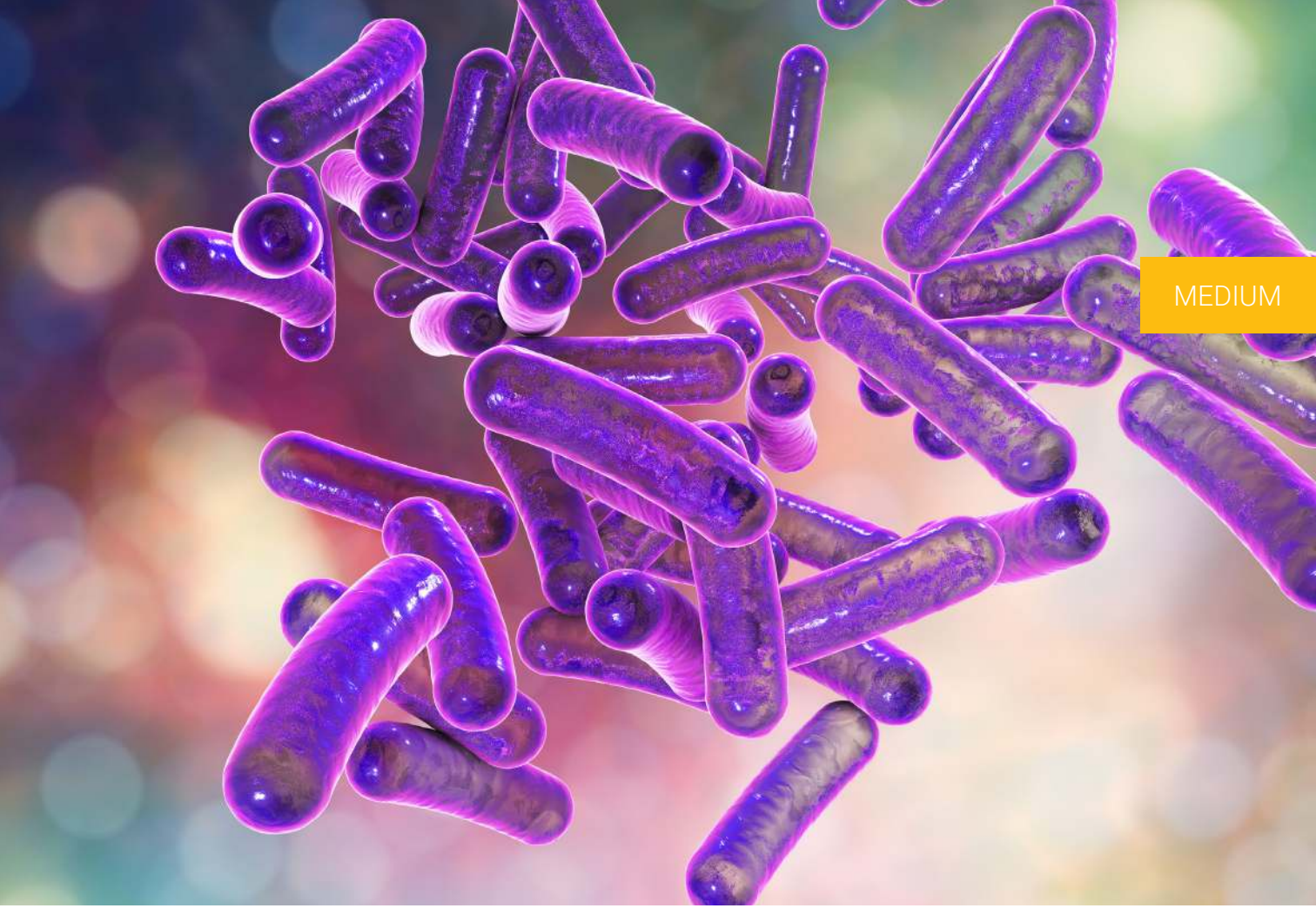
* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** disclaimer: In the absence of third party data, considering the lethal dosages for other gram negative bacteria, 50 mJ/cm² is deemed sufficient to achieve a log 4 reduction against this organism.

Shigella spp., fluoroquinolone-resistant

Shigella can cause diarrhoea, fever, abdominal pain. These bacteria spread in faeces through contact between people, including sexual activity, or through contaminated food, water, or surfaces. Compared with most treatable Shigella infections, antibiotic-resistant shigellosis are harder to treat, increases the cost of treatment and lengthen the illness.

There are an estimated 27,000 antibiotic resistant *Shigella* infections in the United States each year out of a total of 450.000 infections. High-risk groups include young children, homosexuals, people with weakened immune systems, and travelers to countries with unsafe water and inadequate sanitation.

Most Shigella infections resolve on their own without treatment, however, azithromycin and ciprofloxacin are used to reduce severity and shorten the illness to help reduce spread. Shigella infections have become increasingly resistant since 2013. There are frequent reported outbreaks of multidrug-resistant *Shigella* among homosexuals.



3D illustration of *Shigella*

Microorganism specifications

Pathogen size
0.4-0.6 µm x 1-3 µm

Infection risk from environment
MEDIUM

Frequently isolated from
Nurseries and toilet facilities

Approximate colour change on UV-C dosimeter for log 4**

General description
Gram negative bacillus

Survives on surfaces
2 days - 5 months*

UV-C dose for log 4
8.2 mJ/cm²**

Req'd exposure time at 1m for 8.2 mJ/cm²
3 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** Chang JC, et al. Appl Environ Microbiol 1985;49:1361-5. (The source referenced provides a dosage for Shigella sonnei)

Clostridium difficile spores

Clostridioides difficile spores (formally called *Clostridium difficile*) is Gram-positive, anaerobic, spore-forming bacillus and is found in the human intestine. It causes a life-threatening diarrhoea in vulnerable groups of patients, especially those who are elderly or immunocompromised.

It is usually a side-effect of taking antibiotics and occurs commonly in:

- People 65 and older who take antibiotics and receive medical care
- People staying in hospitals and nursing homes for a long period of time
- People with weakened immune systems or previous infection with C. difficile.

Symptoms might start within a few days or several weeks after you begin taking antibiotics and include:

- Diarrhoea: loose, watery faeces for several days
- Fever
- Stomach tenderness
- Loss of appetite
- Nausea

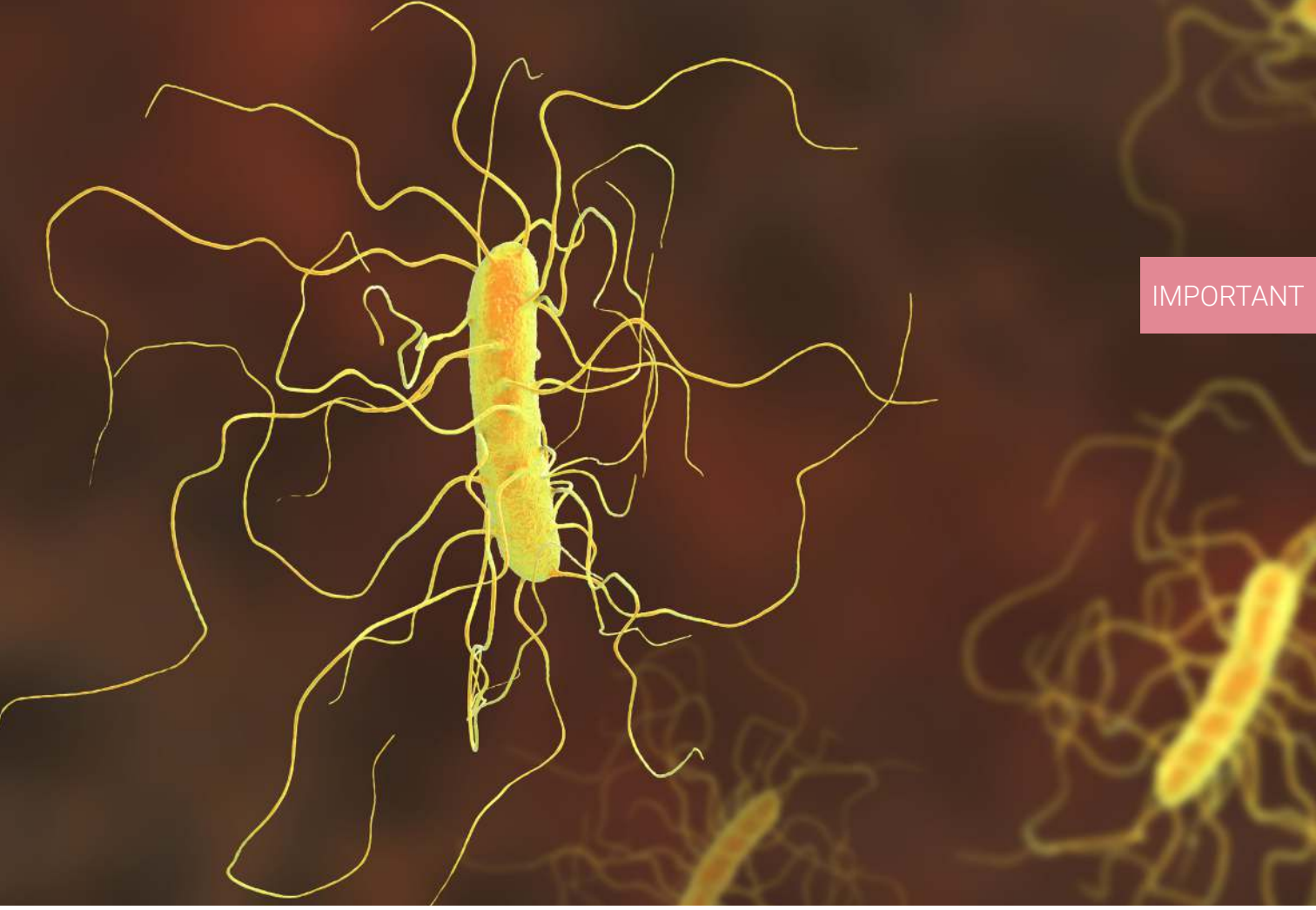
It is easily spread from person to person and is frequently isolated from the environment in rooms occupied by an infected patient. This organism can live for long periods of time in the dust and surfaces of infected hospital environments due the spore it produces. The spore coat consists of high levels of a compound, calcium dipicolinate, which enables the ability to survive for long periods in a dormant state without moisture. *C. difficile spores* is difficult to eradicate from the environment as it is resistant to many of the commonly used disinfectants. It is estimated to cause almost half a million illnesses in the United States each year and about one in six patients who get *C. difficile* spores will get it again in the subsequent two-eight weeks. Within a month of diagnosis, one in 11 people over age 65 died of a healthcare-associated *C. difficile* infection (Source: 2019 AR Threats Report).

C. difficile spores is more resistant to UV-C than many of the other commonly isolated bacteria because of the spore it produces. The UV-C testing has to be carried out on spores, not the vegetative forms.

Independent UVD Robot testing on this microorganism

Melbec	Institute:	Melbec Microbiology, UK
DANISH TECHNOLOGICAL INSTITUTE	Date:	Feb/2019
	Result:	Log 4.5 (99.995%)
	Report ID:	uvd-ict/cd

Full clinical test report available on request



IMPORTANT

3D illustration of *Clostridium difficile spores*

Microorganism specifications

Pathogen size 0.3-2 µm x 1.5-20 µm	**Infection risk from environment** **HIGH**	**Frequently isolated from** High touch areas and patient rooms	**Approximate colour change on UV-C dosimeter for log 3****
General description Gram positive spore forming bacillus	**Survives on surfaces** 5 months*	**UV-C dose for log 3** 90 mJ/cm²**	**Req'd exposure time at 1m for 90 mJ/cm²** 33.3 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** https://rduvc.com/wp-content/uploads/MOOG-Clostridium_difficile_Spore_Inactivation_Study_Using_Ultraviolet-C_Energy.pdf

Candida auris

Candida auris (*C. auris*) is an emerging multidrug-resistant yeast. It can cause severe infections and spreads easily between hospitalized patients and nursing home residents. It was first identified in 2009 in Asia but is now reported world wide. The strains of concern are multidrug-resistant, with some strains resistant to all three available classes of antifungals. It is also showing resistance to some of the common disinfectants in use. The bacteria can be carried on patients' skin without causing infection, allowing spread to others.

C. auris began spreading in the United States in 2015. Reported cases increased 318% in 2018 when compared to the average number of cases reported in 2015 to 2017. A key finding indicated that *C. auris* spreads mostly in long-term healthcare facilities among patients with severe medical problems. There are four strains identified causing the global infections.

C. auris can survive for weeks on surfaces, has reduced susceptibility to quaternary ammonia disinfectants, and can colonize skin. Since products with C. albicans or fungicidal claims may not be effective against *C. auris*, 10% bleach should be used for cleaning the environment.

Independent UVD Robot testing on this microorganism

Melbec Microbiology ✓	Institute:	Melbec Microbiology, UK
Danish Technological Institute	Date:	Sep/2019
	Result:	Log 3 (99.9%)
	Report ID:	uvd-ict/ca

Full clinical test report available on request

IMPORTANT

3D illustration of *Candida auris*

Microorganism specifications

Pathogen size Data not available	Infection risk from environment **HIGH**
Frequently isolated from Surfaces augmented care units	Approximate colour change on UV-C dosimeter for log 3**
General description Branching yeast	Survives on surfaces Multiable weeks*
UV-C dose for log 3 1620 mJ/cm²**	Req'd exposure time at 1m for 1620 mJ/cm² 10 minutes**

*https://www.cdc.gov/fungal/candida-auris/c-auris-health-qa.html

**In the absence of third party data and considering the complex structure of this microorganism, only high dosages of UV-C are recommended. Clinical testing of the UVD Robot delivered a greater than log 3 reduction within 10 minutes

Escherichia coli

Escherichia coli are bacteria found in the environment, foods, and intestines of people and animals. They are a large and diverse group of bacteria. Although most strains of *E. coli* are harmless, others can be highly pathogenic causing diarrhoea, urinary tract infections, respiratory illness and pneumonia, and other illnesses.

Pathogenic *E. coli* strains are categorized into six pathotypes, associated with diarrhoea and collectively are referred to as diarrheagenic *E. coli*. These strains are categorised based on toxins that they produce.

As *E. coli* are found in the intestines of most mammals, it is used as a marker organism for faecal contamination on surfaces and also for water contamination. Therefore , when reports of *E. coli* being found in drinking water, they may not be themselves harmful, but indicates the water is contaminated with faecal organisms and there may be harmful organisms present.

ESBL-producing *E. coli* (ESBL-EC) are increasing among community-onset urinary tract infections (UTI) and is an important public health concern as these organisms are resistant to multiple antimicrobial agents. In addition, ESBL-EC can also have co-resistance to sulphonamide and trimethoprim (SMX/TMP), fluoroquinolones, and aminoglycosides.

Carbapenems are generally considered the drug of choice for the treatment of ESBL-EC infections. However, carbapenems are expensive and very broad-spectrum agents. For the treatment of ESBL-EC cystitis, more narrow antimicrobial agents should also be considered. There has been resistance to carbapenemases detected in this common pathogen and care has to be taken if a person has renal failure when administrating these antibiotics.

E.coli (as a faecal indicator organism) is commonly used to detect the cleanliness of surfaces in the environment.

Independent UVD Robot testing on this microorganism

Melbec	Institute:	Danish Technological institute
DANISH TECHNOLOGICAL INSTITUTE ✓	Date:	June/2017
	Result:	Log 6.1 (99.99991%)
	Report ID:	uvd-ict/ec

Full clinical test report available on request

IMPORTANT

3D illustration of *Escherichia coli*

Microorganism specifications

Pathogen size 1-2 µm x 0.5 µm	Infection risk from environment **HIGH**
Frequently isolated from Bathrooms in the healthcare environment	Approximate colour change on UV-C dosimeter for log 4**
General description Gram negative bacillus	Survives on surfaces 1.5 hours - 16 months*
UV-C dose for log 4 11 mJ/cm²**	Req'd exposure time at 1m for 11 mJ/cm² 4.1 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** Hoyer O. Water Supply 1998,16(1–2): 424-429.

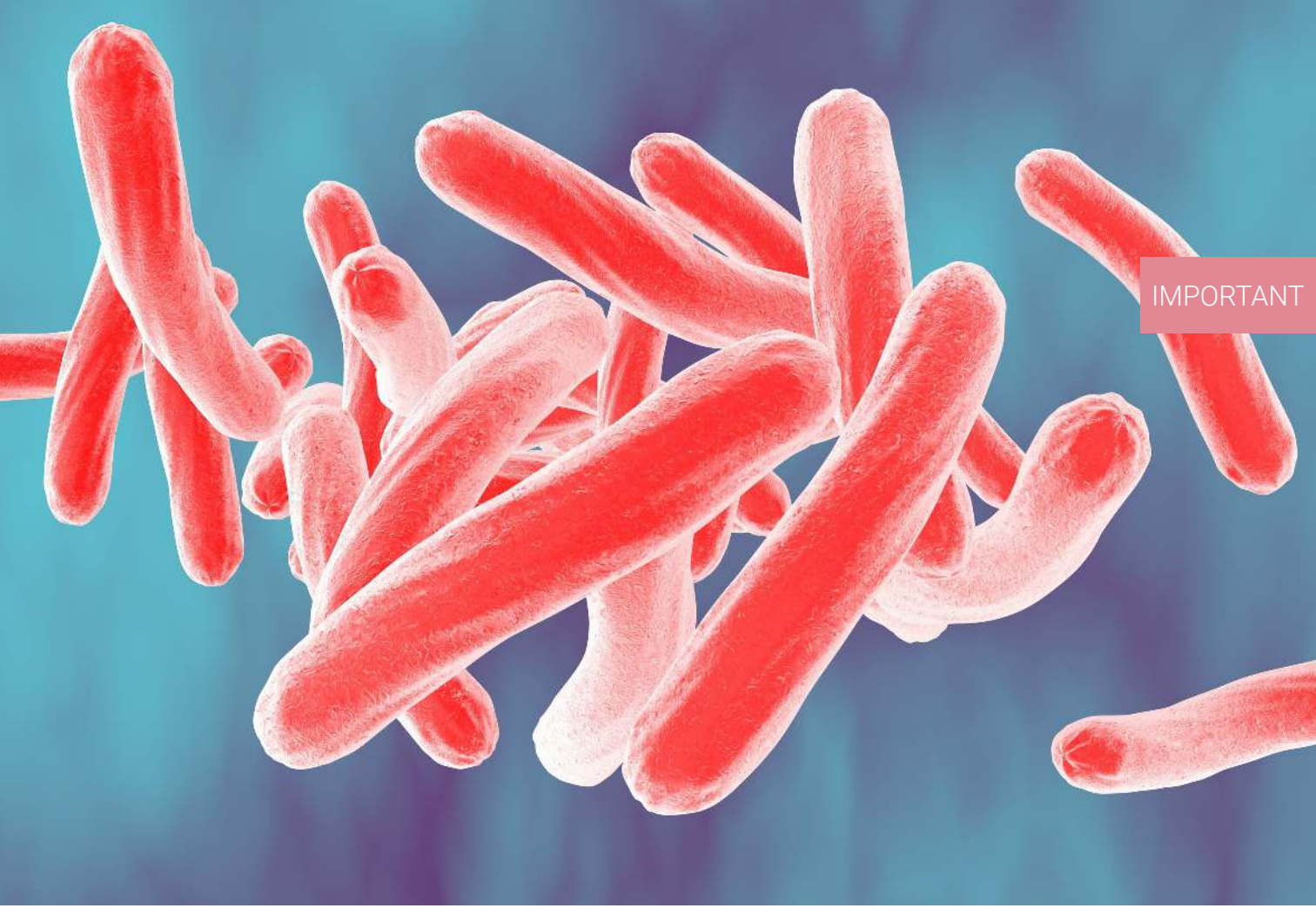
Mycobacterium tuberculosis multi-drug-restistant

Tuberculosis (*TB*) is caused by bacteria that are spread from person to person through the air. It usually affects the lungs, but it can also affect other parts of the body, such as the brain, the kidneys, or the spine. TB is usually treatable and curable but people with TB can die if they do not get proper treatment. Currently there is a global problem with multi-drug-resistant TB (MDR TB) (resistant to two or more TB antibiotics) as these bacteria can float in the air for several hours, depending on the environment. Persons who breathe in the air containing these TB bacteria can become infected.

MDR-TB is a huge problem for people with HIV or other forms of immunosuppression. All age groups are at risk and over 95% of cases and deaths are in developing countries. People with malnutrition are three times more at risk. Globally there were 2.3 million new TB cases in 2018 due to malnutrition.

TB occurs in every part of the world. In 2018, the largest number of new TB cases occurred in the South-East Asian region, with 44% of new cases, followed by the African region, with 24% of new cases and the Western Pacific with 18%. In 2018, 87% of new TB cases occurred in the 30 high TB burden countries. Eight countries accounted for two thirds of the new TB cases: India, China, Indonesia, Philippines, Pakistan, Nigeria, Bangladesh and South Africa.

This is a highly infectious disease and now it has become multi-drug resistant, treatment strategies are failing and prevention of transmission of this airborne disease has become more important than ever. UV-C can destroy airborne bacteria and has been shown to kill *MTB*, making the use of this technology in high risk areas extremely important.



IMPORTANT

3D illustration of *Mycobacterium tuberculosis*

Microorganism specifications

Pathogen size 2-4 µm x 0.2-0.5 µm	**Infection risk from environment** **HIGH**	**Frequently isolated from** Healthcare environments	**Approximate colour change on UV-C dosimeter for log 4****
General description Gram negative bacillus	**Survives on surfaces** 1 day - 4 months*	**UV-C dose for log 4** 25 mJ/cm²**	**Req'd exposure time at 1m for 25 mJ/cm²** 9.3 seconds**

* Kramer, Schwebke & Kampf (2006) Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infectious Diseases. 2006;6(1):130. doi: 10.1186/1471-2334-6-130. ** Light Sources Inc. 2014 (data provided was for a log 1 and log 2 reduction. Log 4 calculated based on the correlation between the log 1 and log 2 dosage)

SARS-Cov-2

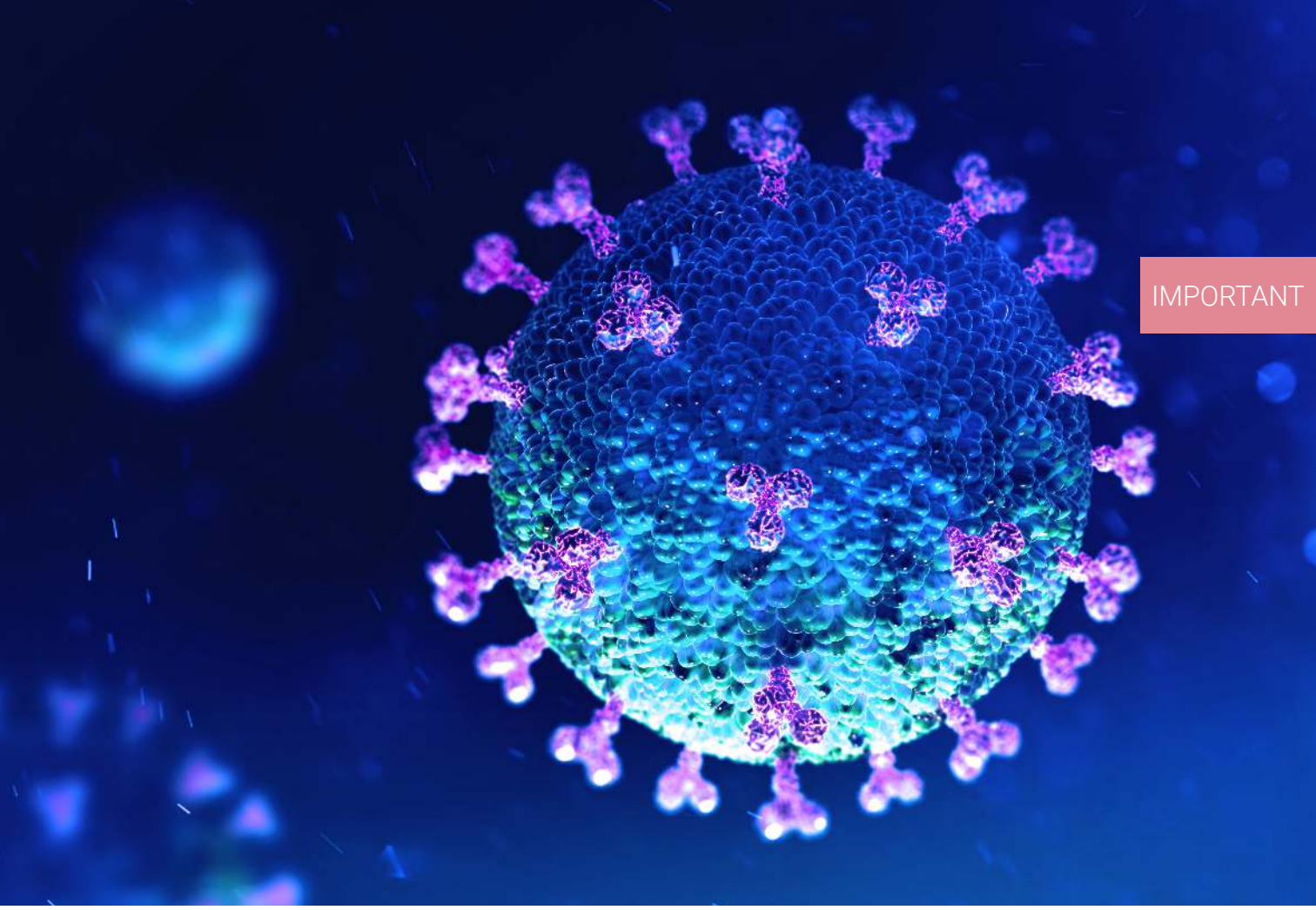
The 2020 pandemic caused by beta coronavirus, SARS-Cov-2, has created huge infection control problems for a wide variety of industries where large numbers of people come together either for leisure or work.

The virus is spread by human-to-human transmission by the inhalation of respiratory droplets and virus-bearing particles spread through the air, or by contact with surfaces contaminated with settled droplets.

Much of the infection control measure rely on social distancing, isolation of infected patients, wearing face coverings and hand hygiene.

The disruption of transmission chains is crucial for managing the outbreak and preventing additional infections, so environmental decontamination continues to be most important for many industries.

Ultraviolet (UV) irradiation is an extensively tested, widely used and effective no-contact method for inactivating viral pathogens and the most common wavelength chosen is 254nm, where viral inactivation is attributed to direct UV-C light absorption and photochemical damage to nucleic acid, leading to the disruption of viral replication.



IMPORTANT

3D illustration of *SARS-Cov-2*

Microorganism specifications

Pathogen size
50 - 200 nm in diameter

Infection risk from environment
HIGH

Frequently isolated from
All surfaces and the air

Approximate colour change on UV-C dosimeter for log 4**

General description
Enveloped positive-sense RNA virus

Survives on surfaces
Up to 3 days

UV-C dose for log 4
22 mJ/cm²**

Req'd exposure time at 1m for 22mJ/cm²
8.2 seconds**

** www.researchsquare.com/article/rs-65742/v1

Frequently Asked Questions

SO HOW DO WE KNOW HOW MUCH UVC IS NEEDED TO KILL MICROORGANISMS IN THE ENVIRONMENT?

Several studies have now been undertaken across a number of accredited laboratories and institutions that demonstrate reproducibility that numbers of bacteria, their spores, fungi, and viruses can all be significantly reduced within a matter of minutes when exposed to UV-C light at certain wavelengths. For example methicillin resistant *Staphylococcus aureus* (MRSA) and multi drug resistant Gram negative bacteria can be reduced by four log (that is from 10000 cells per square cm to one cell per square cm) within five minutes exposure to UV-C at a distance of 1m. In addition, spores of *Clostridiodes difficile* are reduced by four log after a fifteen minute exposure.

This is amazing because the time taken and proximity of the UV-C emitter can be easily achieved within a busy healthcare environment. There is no need for closing off wards and theatres for effective decontamination. There is evidence to show that a room can be decontaminated after terminal cleaning within 30-40mins after it has been vacated.

DOES THE UVC LAMP NEED TO BE AT CLOSE PROXIMITY TO SURFACES WHEN IN OPERATION?

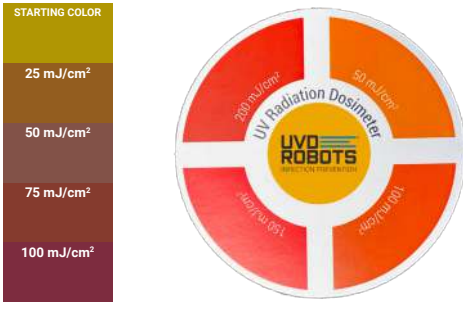
Most work has been done using a UV-C emitter at a distance of 1m. This generates certain levels of UV-C (termed fluence) (measured in mJ/cm2). The greater the distance from the lamp, the longer it takes to reduce organism numbers.

IS THERE SOMETHING THAT CAN SHOW WHEN CERTAIN LEVELS OF UVC ARE ACHIEVED?

A dosimeter (based on color change from yellow to pink) can be used to show that a certain level of UV-C has been achieved. These dosimeters are calibrated to exposure times and reduction of organism numbers.

UVD ROBOTS DOSIMETER REFERENCE CHART

USAGE: These reference charts are intented as a visual indicator to determine if a desired dose of ultraviolet germicidal irradation has been reached. They are designed for use with the UVD Robot UV-C Dosimeters.



WOULD SHADOWING HAVE AN EFFECT ON REDUCTION OF MICROORGANISMS?

Yes it would because the levels of UV-C achieved in the shadows would be reduced. However, with the free movement of the UVD robot, shadowing effects are removed because the robot can move within inches of objects and can overcome the shadows.

WHAT IS THE DIFFERENCE BETWEEN STERILIZATION AND DECONTAMINATION?

Sterilization is the total kill of all microorganisms in an environment or product whereas decontamination is reducing numbers of microorganisms to a very low level to minimize risk of infection.

IS IT OK JUST TO DECONTAMINATE AN ENVIRONMENT TO MAKE IT SAFE?

When disinfectants and other decontaminating methods are used to clean an area, it is expected that whatever is used will reduce contaminating microorganisms by a 3-4 log reduction within five minutes. That is a reduction of 100.000 organisms to 10-100 organisms per square cm in five minutes. Decontaminating the environment is an everyday event and is why we routinely clean an area to keep organism numbers down.

However, if there is a persistent problem in the healthcare environment with repeated infections of the same microorganism, then sterilisation of the room or area may be undertaken as a last resort.

The only way of achieving sterilisation is by using formaldehyde or hydrogen peroxide vapor. Using these methods, the room is totally sealed (windows, doors, vents etc) and following the procedure has to be vented and deemed safe from the toxic gases. This is expensive and costly and demands an individual to be in full PPE and respirators to enter the room to allow fresh air back into the room.

IS IT POSSIBLE TO STERILISE A ROOM WITH UV-C?

This is feasibily possible but would depend upon accessibility to the UV-C (i.e. no shadowing) and time taken. Currently the UV-C is used to decontaminate and reduce numbers but could also be used for longer time periods to reduce numbers to zero. Any shadowing would negate this effect.

IS IT SAFE TO BE IN THE ROOM WHEN THE UV ROBOT IS WORKING?

UV radiation (photons) has sufficient energies to break chemical bonds inside cellular tissues, so cannot be used safely in the presence of animals and humans unless they can be shielded from it.

WORRIED ABOUT MULTI USE WARDS?

Don't be! UV-C does not penetrate glass, fabrics, internal screens or other dividers commonly used in these facilities. You can decontaminate a bay within a multi-use ward with the use of privacy curtains.

- Lytle CD and Sagripanti JS Predicted Inactivation of Viruses of Relevance to Biodefense by Solar Radiation J Virol. 2005 Nov; 79(22): 14244–14252
- http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1039.5476&rep=rep1&type=pdf
- The AR Lab Network includes labs in 50 states, several cities, and Puerto Rico, including seven regional labs and the National Tuberculosis Molecular Surveillance Centre (National TB Centre).

Protocol for testing efficacy of UV-C

PREPARATION OF THE INOCULUM ON SURFACES

Prepare an inoculum (usually a minimal recovery broth) using log phase cultures (approximately 10^7 colony forming units/ml (cfu/ml). As per EN 14561, add 1ml of interfering substance (BSA - 3g/l) to 9ml of test organism (to simulate light soil).

Add 50µl of the inoculum to stainless steel coupons (of the type and grade specified in BS EN 13697 – namely 1.5 mm depth / 20mm diameter stainless steel, manufacturer code 304 2B) and dry for approximately 40 minutes at 36°C.

Place the inoculated stainless steel coupons (held at a 70 degree angle); test coupons (n=3) and unexposed control coupons (n=3) at the same locations. Prepare the unexposed control at the same time as the test coupons by wrapping 3 layers of aluminium foil (to shield from UV-irradiation) around the petri dish containing the coupons.

EXPOSURE TO THE UVD ROBOT

Allow the UVD Robot to 'warm up' for three min and move the robot to within 1m of the samples and allow the robot to remain stationary for different time periods namely five minutes, 10 minutes, 20 minutes and 30 minutes. Carry out the exposure three times for reproducibility

PROCESSING THE COUPONS

On completion of each UV-disinfection cycle, process the coupons by transferring into a set volume of broth, vortex mixing to remove the organisms from the coupon and serially dilute and plate 0.1ml onto the surface of a petri dish. Incubate for 18-24 hours in appropriate conditions and count the colonies for each dilution. Using the mean count, compare the counts to the unexposed controls and calculate the log reduction for the different time period.

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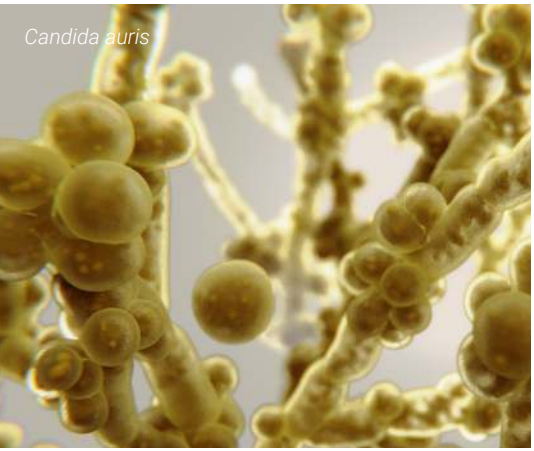

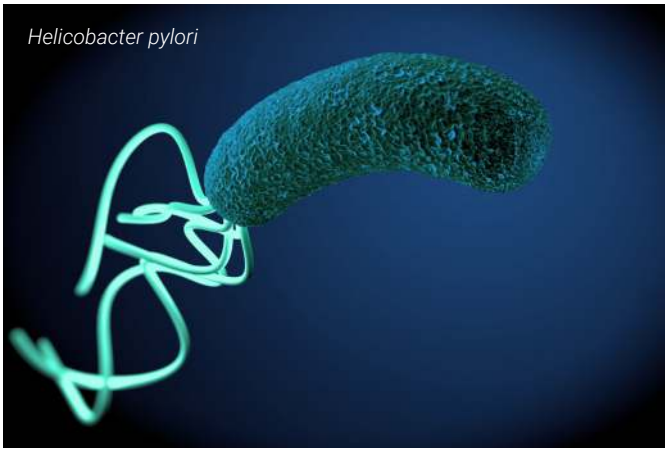

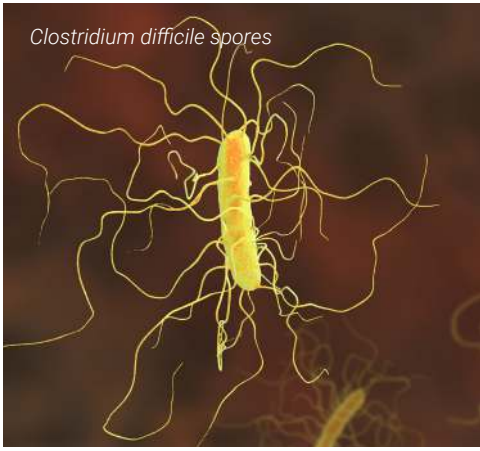

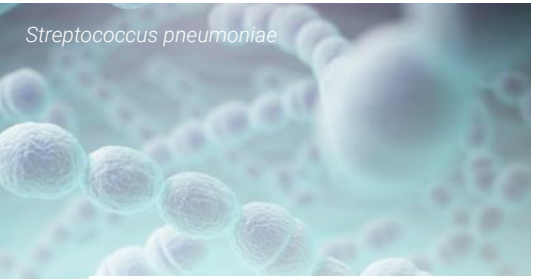

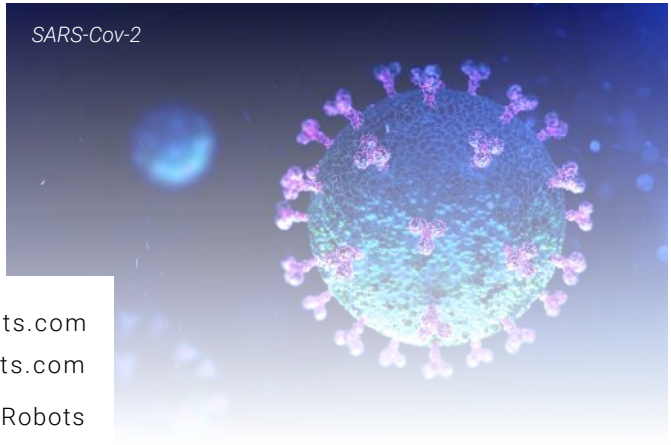

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UVD ROBOTS® HAVE BEEN INDEPENDENTLY TESTED AT THE FOLLOWING LABOROTORIES: