Antiseptic Stewardship

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Biocide Resistance and Clinical Implications

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Foreword

Biocides (disinfectants, antiseptics, preservatives) usage has increased worldwide notably for applications that do not necessarily require the application of biocides, particularly in the home environment. The amount of biocides used in Europe is difficult to quantify as the number of products containing a biocide and biocide applications have increased dramatically in the last 10 years. It is thus logical to assume that microbial exposure to biocides has also increased. Parallel, but not separate, from the increase in biocidal products commercially available is the rise in antimicrobial resistance (AMR) in bacteria, which results primarily from the overuse and misuse of chemotherapeutic antibiotics for human and veterinary medicine, but also for industrial processes such as fermentation. Recent calculations from Lord O'Neil's AMR report to the British government predict human deaths caused by untreatable AMR to reach 10 million worldwide by 2050, well above other diseases including cancer. Biocidal products have a role to play in reducing AMR notably on hard and porous surfaces, with disinfection and antisepsis, and in products through preservation. The increase in biocidal products is most likely due to a better understanding by the public of hygiene concepts and AMR, and the absolute need to control infection, creating opportunities for the industry to meet the need for products that can inhibit or eliminate the risk of infection or spoilage. Although biocidal products play an essential part in controlling micro-organisms on surfaces and in products, the overuse of biocides and biocidal products has raised concerns among regulators, about environmental toxicity following product applications, and on risks associated with emerging bacterial resistance to specific biocidal agents, and cross-resistance to unrelated substances including chemotherapeutic antibiotics. In Europe, the Biocidal Products Regulation now mentioned the need for manufacturers to measure the impact of biocidal products on emerging resistance and cross-resistance, while the US Food and Drug Administration has recently published a rule to restrict the use of a number of cationic and phenolic biocides in certain products, based on potential toxicity and bacterial resistance issues.

Hence, if the use of biocides and biocidal products is necessary and beneficial on the one hand, overuse and misuse of biocides may be detrimental on the other hand. This book looks at the main biocides used in common formulations developed for healthcare applications. It provides useful information on biocide activity against

bacteria and fungi, and evidence of emerging resistance and cross-resistance following biocide exposure. It also dedicates a number of chapters promoting appropriate biocidal product usage and good stewardship of biocidal products in healthcare settings. The subjects presented in this book are topical and of great interests. Overall, the information provided in this book provides a better understanding of the efficacy and limitations of commonly used biocides and their applications.

Cardiff, UK
June 2018

Prof. Jean-Yves Maillard
School of Pharmacy and Pharmaceutical Sciences
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Preface

> *A chemical that constantly stresses bacteria to adapt, and behaviour that promotes antibiotic resistance needs to be stopped immediately when the benefits are null.*
>
> Patrick J. McNamara and Stuart B. Levy (2016)

The indicated use of antiseptics and disinfectants is regarded as a major contribution to prevent the transmission of multidrug- or pan-resistant pathogens. Some antiseptic products, however, contain additional non-volatile active ingredients with a doubtful or sometimes even without a contribution to the overall antimicrobial efficacy. But these agents can at the same time cause adaptation and resistance, mainly among Gram-negative bacterial species. The resistance may even cover other biocidal agents or selected antibiotics. Chlorhexidine digluconate is such a biocidal agent used in different types of products such as alcohol-based hand rubs, antimicrobial soaps, alcohol-based skin antiseptics and antiseptic mouth rinses. In some of the applications, there is good evidence that it contributes to patient safety, e.g. when used in combination with alcohol as a skin antiseptic for the insertion of a central venous catheter or for puncture site care. Its effect in alcohol-based hand rubs, however, is at least doubtful.

After my publication in the Journal of Hospital Infection in 2016 on acquired resistance to chlorhexidine and the proposal to establish an antiseptic stewardship initiative, I have received some very encouraging emails from clinical colleagues who were grateful for the review and who supported the principal idea of an antiseptic stewardship based on their own clinical experience. This type of feedback was motivation enough to look at the entire topic in a broader perspective.

Although the evaluation of biocidal agents was done with a lot of care for completeness and experimental details, I may still have missed some studies. But the overall picture is probably quite complete and allows learning which of the biocidal agents has a higher risk for promoting resistance in which types of pathogens. Healthcare workers are invited to critically look at the product labels in the section “composition” and to find out which of the active agents is in the product even if not declared as an active agent. Regulative authorities are invited to ask the manufacturers about the evidence-based antimicrobial effects of specific substances which may even result in non-approval of specific products if the risks

for selection pressure by a substance outweigh any possible benefits. And manufacturers are invited to take all the findings into account when formulating antiseptic products. At the end, I hope that the book contributes to reducing unnecessary selection pressure by the different types of antiseptic agents.

Greifswald, Germany Günter Kampf

About this Book

For this book, typical antiseptic substances have been selected which are used in various fields of applications (e.g. human medicine, veterinary medicine, food production and handling) and are used in at least two types of antiseptic products (e.g. hand disinfectants, surface disinfectants, skin antiseptics) by at least two manufacturers. Another prerequisite was to have published evidence available for each antiseptic agent allowing a best possible comprehensive review of its antimicrobial efficacy and resistance. One aspect is very important in this context. The summary on each biocidal agent aims to provide a neutral and complete picture but does not intend to favour or disadvantage specific biocidal agents. It does also not intend to favour or disadvantage specific manufacturers or companies.

In the first part of each chapter, the chemical is characterized followed by its typical applications including the regulatory frame in the European Union and the USA. A summary of the activity of each antiseptic agent against bacteria, fungi and mycobacteria is the next part. It includes an overview on MIC values to determine a microbiostatic activity and data from suspension tests to determine a microbiocidal activity obtained with culture collection strains and all other types of clinical and environmental isolates. It also includes a description of the efficacy against the micro-organisms in biofilms. Viruses were not included because adaptation and resistance were regarded as defence mechanisms of living cells. Bacterial spores were also not included because they are considered the most resistant form of a micro-organism anyway so that an adaptation or an acquired resistance is not expectable and is unlikely to change the use of antiseptics.

It is followed by all data on any type of adaptive response by micro-organisms to low-level exposure to the biocidal agent. This may be a change of susceptibility to the biocide itself, to other biocidal agents or antibiotics (e.g. measured by a higher MIC value), a change of biofilm formation, a change of efflux pump activity or a change of horizontal gene transfer. Taking all the information together will hopefully allow to see that some antiseptic agents have a higher risk for microbial adaptation and resistance, and other agents have a lower risk.

Finally, a description of the frequency of resistance can be found, e.g. isolates with high MIC values, contaminated biocidal products or even outbreaks or pseudo-outbreaks of infections caused by contaminated biocidal products. Possible mechanisms of resistance are reviewed such as specific resistance genes, plasmids

and efflux pumps that may extrude deleterious compounds, such as antibiotics, drugs and solvents. Cross-resistance to other biocidal agents and antibiotics is also summarized in this part. Some studies have reported that a species became resistant to an antibiotic based on accepted break points and methods. In this case, an isolate will be described as resistant to the antibiotic. Other authors described an MIC change (e.g. by microdilution or Etest) or a change of the zone of inhibition (e.g. by disc diffusion test) without an assignment to "resistant" or "susceptible". This type of finding will be described as cross-tolerance. In addition, data on biofilm development, removal and fixation are summarized for each antiseptic agent. Based on the agents' summary, it should be possible to establish an antiseptic stewardship initiative.

Contents

About the Author

Günter Kampf is an associate professor for Hygiene and Environmental Medicine at the University of Greifswald, Germany. He has published more than 180 mostly international articles on various aspects of infection control, mainly hand hygiene and surface disinfection. In 2017, he published his second textbook on hand hygiene in German as an editor. He is a recognized medical specialist in Hygiene and Environmental Medicine and has worked for 18 years for a manufacturer of chemical disinfectants, in the last 5 years as a Director Science. Since 2016 he is self-employed and continues his scientific work together with infection control consultancy for hospitals, medical practices and companies with infection control issues (www.guenter-kampf-hygiene.de).

Abbreviations

3MRGN	Isolate with resistance to three of the following four antibiotic classes: acylureidopenicillins, third-generation and fourth-generation cephalosporins, carbapenems and fluoroquinolones
4MRGN	Isolate with resistance to all of the following four antibiotic classes: acylureidopenicillins, third-generation and fourth-generation cephalosporins, carbapenems and fluoroquinolones
A. acidoterrestris	Alicyclobacillus acidoterrestris
A. actinomycetemcomitans	Aggregatibacter actinomycetemcomitans
A. alternata	Alternaria alternata
A. anitratus	Acinetobacter anitratus
A. aphrophilus	Aggregatibacter aphrophilus
A. baumannii	Acinetobacter baumannii
A. calcoaceticus	Acinetobacter calcoaceticus
A. delafieldii	Acidovorax delafieldii
A. elegans	Actinomucor elegans
A. ferrooxidans	Acidithiobacillus ferrooxidans
A. flavipes	Aspergillus flavipes
A. flavus	Aspergillus flavus
A. fumigatus	Aspergillus fumigatus
A. gyllenbergii	Acinetobacter gyllenbergii
A. hydrophila	Aeromonas hydrophila
A. israelii	Actinomyces israelii
A. jandaei	Aeromonas jandaei
A. junii	Acinetobacter junii
A. laidlawii	Acheloplasma laidlawii
A. lwoffii	Acinetobacter lwoffii
A. naeslundii	Actinomyces naeslundii
A. nidulans	Aspergillus nidulans
A. niger	Aspergillus niger
A. nosocomialis	Acinetobacter nosocomialis
A. ochraceus	Aspergillus ochraceus

A. odontolyticus	Actinomyces odontolyticus
A. oleivorans	Acinetobacter oleivorans
A. parasiticus	Aspergillus parasiticus
A. proteolyticus	Aranicola proteolyticus
A. salmonicida	Aeromonas salmonicida
A. terreus	Aspergillus terreus
A. ustus	Aspergillus ustus
A. versicolor	Aspergillus versicolor
A. viscosus	Actinomyces viscosus
A. westerdijkiae	Aspergillus westerdijkiae
A. xylosoxidans	Achromobacter xylosoxidans
Ag-NP	Silver nanoparticles
ASTM	American Society for Testing and Materials
ATCC	American Type Culture Collection
B. abortus	Brucella abortus
B. adolescentis	Bifidobacterium adolescentis
B. afzelii	Borrelia afzelii
B. amyloliquefaciens	Bacillus amyloliquefaciens
B. animalis	Bifidobacterium animalis
B. bifidum	Bifidobacterium bifidum
B. breve	Bifidobacterium breve
B. burgdorferi	Borrelia burgdorferi
B. catenulatum	Bifidobacterium catenulatum
B. cenocepacia	Burkholderia cenocepacia
B. cepacia	Burkholderia cepacia
B. cereus	Bacillus cereus
B. diminuta	Brevundimonas diminuta
B. fragilis	Bacteroides fragilis
B. garinii	Borrelia garinii
B. gingivalis	Bacteroides gingivalis
B. infantis	Bifidobacterium infantis
B. intermedius	Bacteroides intermedius
B. licheniformis	Bacillus licheniformis
B. longum	Bifidobacterium longum
B. mallei	Burkholderia mallei
B. megaterium	Bacillus megaterium
B. melaninogenicus	Bacteroides melaninogenicus
B. melitensis	Brucella melitensis
B. petrii	Bordetella petrii
B. pseudocatenulatum	Bifidobacterium pseudocatenulatum
B. pseudolongum	Bifidobacterium pseudolongum
B. pseudomallei	Burkholderia pseudomallei
B. pumilus	Bacillus pumilus
B. sanguinis	Brevibacterium sanguinis
B. spicifera	Bipolaris spicifera

B. stearothermophilus	Bacillus stearothermophilus
B. subtilis	Bacillus subtilis
B. suis	Bifidobacterium suis
B. thailandensis	Burkholderia thailandensis
B. thermoacidophilum	Bifidobacterium thermoacidophilum
C. acidovorans	Comamonas acidovorans
C. albicans	Candida albicans
C. argentea	Candida argentea
C. ciferrii	Candida ciferrii
C. concisus	Campylobacter concisus
C. difficile	Clostridium difficile
C. diphtheriae	Corynebacterium diphtheriae
C. dubliniensis	Candida dubliniensis
C. famata	Candida famata
C. funicola	Chaetomium funicola
C. gingivalis	Capnocytophaga gingivalis
C. glabrata	Candida glabrata
C. globosum	Chaetomium globosum
C. guilliermondii	Candida guilliermondii
C. indologenes	Chryseobacterium indologenes
C. intermedia	Candida intermedia
C. intermedius	Citrobacter intermedius
C. jeikeium	Corynebacterium jeikeium
C. jejuni	Campylobacter jejuni
C. kefyr	Candida kefyr
C. koseri	Citrobacter koseri
C. krusei	Candida krusei
C. liriodendri	Cylindrocarpon liriodendri
C. lusitaniae	Candida lusitaniae
C. luteola	Chryseomonas luteola
C. macrodidymum	Cylindrocarpon macrodidymum
C. matruchotti	Corynebacterium matruchotti
C. melibiosica	Candida melibiosica
C. meningosepticum	Chryseobacterium meningosepticum
C. metallidurans	Cupriavidus metallidurans
C. neoformans	Cryptococcus neoformans
C. norvegensis	Candida norvegensis
C. novyi	Clostridium novyi
C. ochracea	Capnocytophaga ochracea
C. oleophila	Candida oleophila
C. orthopsilosis	Candida orthopsilosis
C. parapsilosis	Candida parapsilosis
C. pelliculosa	Candida pelliculosa
C. perfringens	Clostridium perfringens
C. piscicola	Carnobacterium piscicola

C. pseudogenitalium	Corynebacterium pseudogenitalium
C. pseudotropicalis	Candida pseudotropicalis
C. rectus	Campylobacter rectus
C. renale	Corynebacterium renale
C. rodentium	Citrobacter rodentium
C. sakazakii	Cronobacter sakazakii
C. sake	Candida sake
C. striatum	Corynebacterium striatum
C. trachomatis	Chlamydia trachomatis
C. tropicalis	Candida tropicalis
C. uniguttulatus	Cryptococcus uniguttulatus
C. utilis	Candida utilis
C. xerosis	Corynebacterium xerosis
CAS	Chemical abstracts service
CFU	Colony-forming units
CHA	Chlorhexidine diacetate
CHG	Chlorhexidine digluconate
CIP	Collection of Institut Pasteur
CMCC	National Center for Medical Culture Collections
CNS	Coagulase-negative staphylococci
D. acidovorans	Delftia acidovorans
D. hansenii	Debaryomyces hansenii
DSM	Deutsche Sammlung von Mikroorganismen
DT50	50% dissipation time
E. aerogenes	Enterobacter aerogenes
E. amylovora	Erwinia amylovora
E. asburiae	Enterobacter asburiae
E. avium	Enterococcus avium
E. casseliflavus	Enterococcus casseliflavus
E. cloacae	Enterobacter cloacae
E. coli	Escherichia coli
E. corrodens	Eikenella corrodens
E. durans	Enterococcus durans
E. faecalis	Enterococcus faecalis
E. gergoviae	Enterobacter gergoviae
E. hirae	Enterococcus hirae
E. ludwigii	Enterobacter ludwigii
E. nigrum	Epicoccum nigrum
E. nodatum	Eubacterium nodatum
E. raffinosus	Enterococcus raffinosus
E. repens	Eurotium repens
E. rhusiopathiae	Erysipelothrix rhusiopathiae
E. saccharolyticus	Enterococcus saccharolyticus
E. solitarius	Enterococcus solitarius
ECHA	European Chemicals Agency

ECOFF	Epidemiological cut-off value
EN	European norm
EPA	Environmental Protection Agency
ESBL	Extended spectrum β-lactamase
F. alocis	Filifactor alocis
F. indologenes	Flavobacterium indologenes
F. lichenicola	Fusarium lichenicola
F. noatunensis	Francisella noatunensis
F. nucleatum	Fusobacterium nucleatum
F. oryzihabitans	Flavimonas oryzihabitans
F. oxysporum	Fusarium oxysporum
F. proliferatum	Fusarium proliferatum
F. psychrophilum	Flavobacterium psychrophilum
F. solani	Fusarium solani
F. tularensis	Francisella tularensis
F. verticillioides	Fusarium verticillioides
FDA	Food and Drug Administration
G. haemolysans	Gemella haemolysans
G. vaginalis	Gardnerella vaginalis
h	Hour(s)
H. alvei	Hafnia alvei
H. anomala	Hansenula anomala
H. burtonii	Hyphopichia burtonii
H. flavidus	Humicoccus flavidus
H. gallinarum	Halonella gallinarum
H. influenzae	Haemophilus influenzae
H. parainfluenzae	Haemophilus parainfluenzae
H. parasuis	Haemophilus parasuis
H. pylori	Helicobacter pylori
H. valbyensis	Hanseniaspora valbyensis
ICU	Intensive care unit
IUPAC	International Union of Pure and Applied Chemistry
JCM	Japanese Collection of Microorganisms
K. aerogenes	Klebsiella aerogenes
K. apiculata	Kloeckera apiculata
K. oxytoca	Klebsiella oxytoca
K. planticola	Klebsiella planticola
K. pneumoniae	Klebsiella pneumoniae
K. quasipneumoniae	Klebsiella quasipneumoniae
K. terrigena	Klebsiella terrigena
L. acidophilus	Lactobacillus acidophilus
L. amylovorus	Lactobacillus amylovorus
L. brevis	Lactobacillus brevis
L. brunescens	Lysobacter brunescens
L. bulgaricus	Lactobacillus bulgaricus

L. coryniformis	Lactobacillus coryniformis
L. fermentum	Lactobacillus fermentum
L. garvieae	Lactococcus garvieae
L. grayi	Listeria grayi
L. helveticus	Lactobacillus helveticus
L. innocua	Listeria innocua
L. lactis	Lactococcus lactis
L. mesenteroides	Leuconostoc mesenteroides
L. monocytogenes	Listeria monocytogenes
L. odontolyticus	Lactobacillus odontolyticus
L. paracasei	Lactobacillus paracasei
L. pentosus	Lactobacillus pentosus
L. plantarum	Lactobacillus plantarum
L. pneumophila	Legionella pneumophila
L. pseudomesenteroides	Leuconostoc pseudomesenteroides
L. reuteri	Lactobacillus reuteri
L. rhamnosus	Lactobacillus rhamnosus
L. salivarius	Lactobacillus salivarius
L. seeligeri	Listeria seeligeri
L. welshimeri	Listeria welshimeri
M. abscessus	Mycobacterium abscessus
M. adhaesivum	Methylobacterium adhaesivum
M. aquaticum	Methylobacterium aquaticum
M. avium	Mycobacterium avium
M. bolletii	Mycobacterium bolletii
M. bovis	Mycobacterium bovis
M. canis	Microsporum canis
M. chelonae	Mycobacterium chelonae
M. circinelloides	Mucor circinelloides
M. fortuitum	Mycobacterium fortuitum
M. frederiksbergense	Mycobacterium frederiksbergense
M. fructicola	Metschnikowia fructicola
M. furfur	Malassezia furfur
M. gallisepticum	Mycoplasma gallisepticum
M. gypseum	Microsporum gypseum
M. kansasii	Mycobacterium kansasii
M. luteus	Micrococcus luteus
M. marinum	Mycobacterium marinum
M. massiliense	Mycobacterium massiliense
M. morganii	Morganella morganii
M. nonchromogenicum	Mycobacterium nonchromogenicum
M. osloensis	Moraxella osloensis
M. pachydermatis	Malassezia pachydermatis
M. phlei	Mycobacterium phlei
M. phyllosphaeriae	Microbacterium phyllosphaeriae

M. pneumoniae	Mycoplasma pneumoniae
M. racemosus	Mucor racemosus
M. rhodesianum	Methylobacterium rhodesianum
M. ruber	Monascus ruber
M. scrofulaceum	Mycobacterium scrofulaceum
M. slooffiae	Malassezia slooffiae
M. smegmatis	Mycobacterium smegmatis
M. suaveolens	Moniliella suaveolens
M. sympodialis	Malassezia sympodialis
M. terrae	Mycobacterium terrae
M. testaceum	Microbacterium testaceum
M. tuberculosis	Mycobacterium tuberculosis
M. xenopi	Mycobacterium xenopi
MBC	Minimum bactericidal concentration
MBEC	Minimum biofilm-eliminating concentration
MDR	Multidrug resistant
MIC	Minimum inhibitory concentration
MIC_{max}	Highest MIC value
min	Minute(s)
MRCNS	Methicillin-resistant coagulase-negative staphylococci
MRSA	Methicillin-resistant Staphylococcus aureus
MRSE	Methicillin-resistant Staphylococcus epidermidis
MRSP	Methicillin-resistant Staphylococcus pseudointermedius
MSCNS	Methicillin-susceptible coagulase-negative staphylococci
MSSA	Methicillin-susceptible Staphylococcus aureus
MSSP	Methicillin-susceptible Staphylococcus pseudointermedius
MTCC	Microbial Type Culture Collection and Gene Bank
N. asteroides	Nocardia asteroides
N. pseudofischeri	Neosartorya pseudofischeri
N. subflava	Neisseria subflava
NCIMB	National Collection of Industrial Food and Marine Bacteria
NCPF	National Collection of Pathogenic Fungi
NCTC	National Collection of Type Cultures
O. anthropi	Ochrobactrum anthropi
P	Commercial product
P. acnes	Propionibacterium acnes
P. aeruginosa	Pseudomonas aeruginosa
P. agglomerans	Pantoea agglomerans
P. alcalifaciens	Providencia alcalifaciens
P. aleophilum	Phaeoacremonium aleophilum

P. alkylphenolia	Pseudomonas alkylphenolia
P. anaerobius	Peptostreptococcus anaerobius
P. ananatis	Pantoea ananatis
P. anomala	Pichia anomala
P. aurantiogriseum	Penicillium aurantiogriseum
P. caseifulvum	Penicillium caseifulvum
P. chlamydospora	Phaeomoniella chlamydospora
P. chlororaphis	Pseudomonas chlororaphis
P. chrysogenum	Penicillium chrysogenum
P. citrinum	Penicillium citrinum
P. commune	Penicillium commune
P. corylophilum	Penicillium corylophilum
P. crustosum	Penicillium crustosum
P. denticola	Prevotella denticola
P. diminuta	Pseudomonas diminuta
P. discolor	Penicillium discolor
P. endodontalis	Porphyromonas endodontalis
P. expansum	Penicillium expansum
P. fluorescens	Pseudomonas fluorescens
P. fragi	Pseudomonas fragi
P. gingivalis	Porphyromonas gingivalis
P. intermedia	Prevotella intermedia
P. lundensis	Pseudomonas lundensis
P. marginalis	Pseudomonas marginalis
P. melaninogenica	Prevotella melaninogenica
P. mexicana	Pseudoxanthomonas mexicana
P. micra	Parvimonas micra
P. micros	Peptostreptococcus micros
P. mirabilis	Proteus mirabilis
P. morganii	Proteus morganii
P. multocida	Pasteurella multocida
P. nalgiovense	Penicillium nalgiovense
P. nigrescens	Prevotella nigrescens
P. nitroreducens	Pseudomonas nitroreducens
P. nitroreductans	Pseudomonas nitroreductans
P. norvegensis	Pichia norvegensis
P. ohmeri	Pichia ohmeri
P. paneum	Penicillium paneum
P. putida	Pseudomonas putida
P. pyocyanea	Pseudomonas pyocyanea
P. rettgeri	Proteus rettgeri
P. roqueforti	Penicillium roqueforti
P. solitum	Penicillium solitum
P. stutzeri	Pseudomonas stutzeri
P. verrucosum	Penicillium verrucosum

P. vesicularis	Pseudomonas vesicularis
P. vulgaris	Proteus vulgaris
PRSP	Penicillin-resistant Streptococcus pneumoniae
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl chloride
QAC	Quaternary ammonium compound
R. dentocariosa	Rothia dentocariosa
R. erythropolis	Rhodococcus erythropolis
R. microsporus	Rhizopus microsporus
R. mucilaginosa	Rhodotorula mucilaginosa
R. nigricans	Rhizopus nigricans
R. pickettii	Ralstonia pickettii
R. planticola	Raoultella planticola
R. rubra	Rhodotorula rubra
R. rubrum	Rhodospirillum rubrum
S	Solution of antiseptic agent
s	Second(s)
S. Anatum	Salmonella Anatum
S. anginosus	Streptococcus anginosus
S. apiospermum	Scedosporium apiospermum
S. arboriculus	Saccharomyces arboriculus
S. aureus	Staphylococcus aureus
S. bayanus	Saccharomyces bayanus
S. brevicaulis	Scopulariopsis brevicaulis
S. capitis	Staphylococcus capitis
S. caprae	Staphylococcus caprae
S. cariocanus	Saccharomyces cariocanus
S. carlsbergensis	Saccharomyces carlsbergensis
S. cerevisiae	Saccharomyces cerevisiae
S. choleraesuis	Salmonella choleraesuis
S. chromogenes	Staphylococcus chromogenes
S. cohnii	Staphylococcus cohnii
S. constellatus	Streptococcus constellatus
S. delphini	Staphylococcus delphini
S. enterica	Salmonella enterica
S. Enteritidis	Salmonella Enteritidis
S. epidermidis	Staphylococcus epidermidis
S. equorum	Staphylococcus equorum
S. fleurettii	Staphylococcus fleurettii
S. flexneri	Shigella flexneri
S. gordonii	Streptococcus gordonii
S. Hadar	Salmonella Hadar
S. haemolyticus	Staphylococcus haemolyticus
S. hominis	Staphylococcus hominis
S. hyicus	Staphylococcus hyicus

S. Infantis	Salmonella Infantis
S. intermedius	Streptococcus intermedius
S. Kentucky	Salmonella Kentucky
S. kloosii	Staphylococcus kloosii
S. kudriavzevii	Saccharomyces kudriavzevii
S. lentus	Staphylococcus lentus
S. liquefaciens	Serratia liquefaciens
S. lugdunensis	Staphylococcus lugdunensis
S. maltophilia	Stenotrophomonas maltophilia
S. marcescens	Serratia marcescens
S. mikatae	Saccharomyces mikatae
S. mitis	Streptococcus mitis
S. mizutae	Sphingobacterium mizutae
S. multivorum	Sphingobacterium multivorum
S. mutans	Streptococcus mutans
S. oralis	Streptococcus oralis
S. paradoxus	Saccharomyces paradoxus
S. parasanguinis	Streptococcus parasanguinis
S. pasteuri	Staphylococcus pasteuri
S. paucimobilis	Sphingomonas paucimobilis
S. pneumoniae	Streptococcus pneumoniae
S. pombe	Schizosaccharomyces pombe
S. proteamaculans	Serratia proteamaculans
S. pseudintermedius	Staphylococcus pseudintermedius
S. putrefaciens	Shewanella putrefaciens
S. pyogenes	Streptococcus pyogenes
S. salivarius	Streptococcus salivarius
S. sanguinis	Streptococcus sanguinis
S. sanguis	Streptococcus sanguis
S. saprophyticus	Staphylococcus saprophyticus
S. schleiferi	Staphylococcus schleiferi
S. sciuri	Staphylococcus sciuri
S. Senftenberg	Salmonella Senftenberg
S. simulans	Staphylococcus simulans
S. sobrinus	Streptococcus sobrinus
S. soli	Sphingomonas soli
S. sonnei	Shigella sonnei
S. spiritivorum	Sphingobacterium spiritivorum
S. thermophilus	Streptococcus thermophilus
S. Thompson	Salmonella Thompson
S. Typhimurium	Salmonella Typhimurium
S. uvarum	Saccharomyces uvarum
S. viridians	Streptococcus viridians
S. warneri	Staphylococcus warneri
S. wittichii	Sphingomonas wittichii

S. xiamenensis	Shewanella xiamenensis
S. xylosus	Staphylococcus xylosus
S. yanoikuyae	Sphingobium yanoikuyae
SCCS	Scientific Committee on Consumer Safety
SEM	Scanning electron microscopy
t	Ton(s)
T. asahii	Trichosporon asahii
T. delbrueckii	Torulaspora delbrueckii
T. forsythia	Tannerella forsythia
T. harzianum	Trichoderma harzianum
T. longibrachiatum	Trichoderma longibrachiatum
T. mentagrophytes	Trichophyton mentagrophytes
T. rubrum	Trichophyton rubrum
T. viride	Trichoderma viride
T. whipplei	Tropheryma whipplei
V. alginolyticus	Vibrio alginolyticus
V. atypica	Veillonella atypica
V. cholerae	Vibrio cholerae
V. dispar	Veillonella dispar
V. indigofera	Vogesella indigofera
V. parahaemolyticus	Vibrio parahaemolyticus
V. parvula	Veillonella parvula
V. vulnificus	Vibrio vulnificus
v/v	Volume by volume
VBNC	Viable but non-culturable
VISA	Vancomycin intermediate-resistant Staphylococcus aureus
VISE	Vancomycin intermediate-resistant Staphylococcus epidermidis
VRE	Vancomycin-resistant Enterococcus spp.
w/w	Weight by weight
WD	Washer disinfector
WHO	World Health Organization
X. aerolatus	Xenophilus aerolatus
X. citri	Xanthomonas citri
X. maltophilia	Xanthomonas maltophilia
Y. enterocolitica	Yersinia enterocolitica
Y. pestis	Yersinia pestis
Y. pseudotuberculosis	Yersinia pseudotuberculosis
Y. ruckeri	Yersinia ruckeri

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