New Material Surface for Water Condensate

Thomas Pottage[1], Sarah Dyer[1], Susan Paton[1], Ginny Moore[1], Lucie Campagnolo[2], Audrey Berthier[2], Peter Stephenson[3] and Allan Bennett[1] Email: thomas.pottage@phe.gov.uk

[1]Public Health England, Porton Down, UK; [2]MEDES, Toulouse, France, [3]Sefton Technologies Ltd, Liverpool, UK

Public Health England

Protecting and improving the nation's health

Introduction

Microorganisms exhibit a variety of physiological and genetic responses to environmental stresses, and consequently are capable of surviving within almost any environment. Microorganisms can attach to and degrade a wide variety of materials deriving particular advantages from adhesion, not least the ability to readily scavenge available water and nutrients. Once attached and under favourable conditions cells can multiply and develop into dynamic biofilms that may be detrimental to the substrate.

In the context of manned spaceflight, reducing microbial surface contamination is essential to control biofouling, biodegradation and transmission of infection. These issues will become increasingly important particularly in the context of future manned missions of longer duration, higher isolation and the utilisation of an increasing number of closed loop life support systems. There is a need to develop and employ effective antimicrobial and/or antifouling surfaces to help inactivate microorganisms and/or reduce bacterial attachment. Such surfaces could not only reduce biodegradation and system failures due to microbial colonisation, but could also help protect the health of the crew and therefore the mission objective(s).

This project aims to develop a standardised, repeatable testing regimen for antimicrobial surfaces with spaceflight applications at the air/solid and liquid/solid interfaces.

Surface Contamination

Microbial contamination on a circuit board on Mir

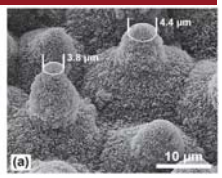
Fungal contamination sampled onboard the ISS. Image credit: NASA

Work Logic

TN 1.1 - Review on the Design of Antimicrobial Surfaces

A wide range of literature, including peer-reviewed scientific manuscripts and grey literature, was analysed to produce a review of antimicrobial/antifouling surfaces. The types of surfaces that are currently available have been described together with their mode of action. Future technologies or those under development and in their infancy have also been reviewed, although less information is available. Details regarding the use and application of these surfaces, both in terrestrial and extra-terrestrial settings, has also been provided.

Specific details regarding the design and manufacture of the different surfaces were investigated. For example, whether the surface incorporates the active agent or is engineered after manufacture; application of the active agent post-production would possibly require reapplication of the agent during use, particularly if the antimicrobial properties were seen to decrease. Literature relating to the impact of the active agent(s) on human health and if microbial resistance could develop over time was also reviewed.



SEM image of a lotus leaf. Ensikat, *et al*. 2011

TN 1.2 – Review on Methodologies/Standards for Characterisation of Antimicrobial Surfaces

A review of the current literature was undertaken to determine the most up to date methodologies and techniques for characterising antimicrobial surfaces against a range of parameters, including but not limited to; antimicrobial effectiveness, duration/stability, specificity, biocompatibility and/or toxicological effect for human and environment. The TN was split into 2 sub-tasks:

a) MEDES identified the constraints and methodologies for evaluating antimicrobial surfaces on board the ISS including the identification of references / applicable documents and methodologies. The document lists and analyses potential scenarios / areas for utilisation of antimicrobial surfaces on manned spacecraft and cargos and evaluates standards to ensure the compatibility, safety and approval of such surfaces, based in particular on applicable documents for ISS.

b) PHE reviewed current terrestrial standards and methodologies used to determine the efficacy of antimicrobial surfaces from a range of sectors. The parameters used in these tests have been critically reviewed in detail.

TN 2 - Identification of Testing Parameters for Surfaces

This document examines the methodologies used in the testing of terrestrial antimicrobial and antifouling surfaces and combines these with the important parameters found on manned space craft. The identified parameters include those covered in current terrestrial standards, such as; challenge organisms, inoculation levels and methods, recovery and assay methods, but also identifies those of top concern during space missions, such as the organisms encountered on manned spacecraft and the unique environmental conditions.

Once established, each test parameter has been evaluated in the context of future long duration space missions. If the parameter can be replicated terrestrially, any risks associated with this replication have been identified and a recommendation for a final test standard has been made. The evaluation of each parameter was achieved via a trade-off between what is important in space versus what can be feasibly performed experimentally to produce meaningful results within and between different laboratories.

Laboratory Equipment

A climate controlled chamber and a drip flow bioreactor that will be used during the project to produce stable conditions during surface testing

Parameters to be tested

Parameters selected for materials at the air/surface interface

Parameter	Rank	Suggested value (range)
Challenge organism	1	*A. niger, S. epidermidis*
Inoculum conc.	1	$5x10^5$ cfu/test (±0.5 $\log_{10}$)
Reproducibility	2	Tolerance determined during validation
Inoculation method	3	Spot inoc./aerosol method(v)
Test Duration	3	1hr – 2 weeks(v)
RH of air	4	50% (±20%)
Temperature	4	21°C (±2°C)
Recovery	5	Liquid washing ± neutralisers(v)
Assay	5	Culture
Sterilisation	5	Autoclaving
Interfering substances	6	0.03%BSA/0.3%BSA
Leaching	6	Zone of Inhibition (± solution test)
Composition of air	7	Lab-supplied
Material size	7	$4cm^2$ and $25cm^2$
Pressure of air	8	975 mbar (±76 mbar)
Efficacy level	9	1 or 3 $\log_{10}$ reduction
Deterioration	10	Adapted with future cleaning protocols
Gravity	11	N/A
Radiation	12	Conditions within laboratory
Dormancy	12	Not considered within this study

Parameters selected for materials at the liquid/surface interface

Parameter	Rank	Suggested value (range)
Challenge organism	1	*P. aeruginosa*
Inoculum conc.	1	$5x10^6$ cfu/test (±0.5 $\log_{10}$)
Flow rate/shear	2	As per CDC or DFR bioreactors
Composition of liquid	3	TSB ± contaminants
Temperature of liquid	3	Suggested 21°C (±2°C)
Test Duration	3	48 hours – 7 days
Reproducibility	4	Tolerance determined during validation
Leaching	4	Zone of Inhibition and Solution test
Inoculation method	5	Drip flow bioreactor
Sterilisation	5	Autoclaving
Material size	6	Drip flow bioreactor
Recovery	7	Microscopy (± culture)
Efficacy level	8	>50% of control surface
Deterioration	9	Adapted with future cleaning protocols
Gravity	10	N/A
Radiation levels	11	Conditions within laboratory
Dormancy	11	Not considered within this study

Future Work

Currently the laboratory phase of the project is being undertaken, where validation and demonstration of achieving each parameter is being completed.

The validation of the test platforms will demonstrate that the parameters are achievable and reproducible.

The ESA will then review the protocols developed and the project will then progress to the test performance phase, where antimicrobial materials will be tested using the protocols. At the end of this phase recommendations will be made and standard test methods finalised.

Acknowledgments

This project is funded by the European Space Agency under project number: 4000120584/17/NL/KML/md