Antimicrobial resistant pathogens in space environment: challenges and potential solutions

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Relevance of Antimicrobials in Space Research

- **Astronauts susceptible to infection:**
  - Closed system
  - Human immune response altered
  - Space conditions can increase bacterial virulence, antibiotic resistance, secondary metabolite and EPS production, biofilm formation
  - **Damage of technical equipment through bacterial colonisation**
  - Common disinfectans often unsuitable (flammable, chemical corrosion)

Application of Antimicrobial Surfaces on the ISS

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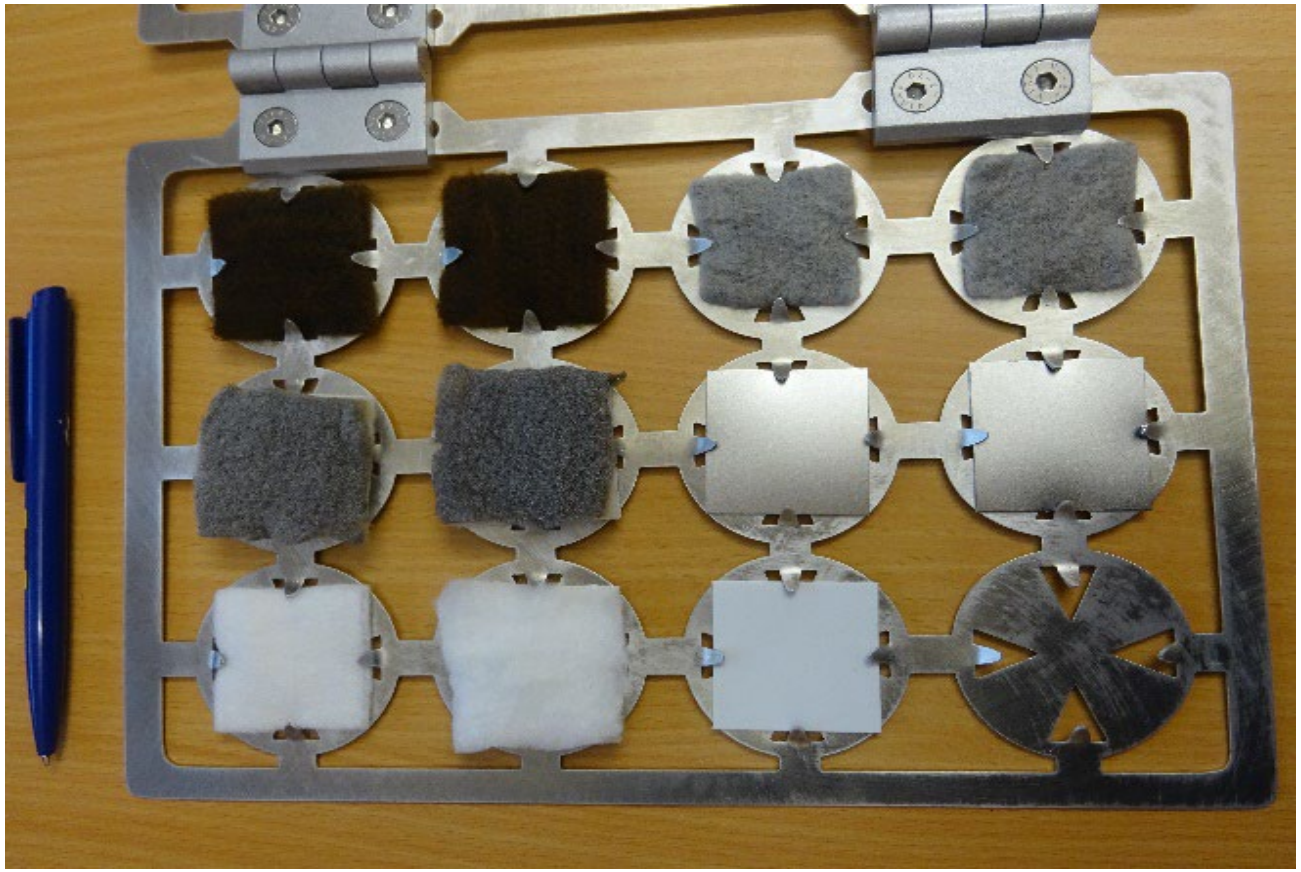
AGXX®, GOX and AGXX-GOX-Combinations

- Specially structured antimicrobial coatings
- On diverse carriers, e.g. fleece, plastic, metals

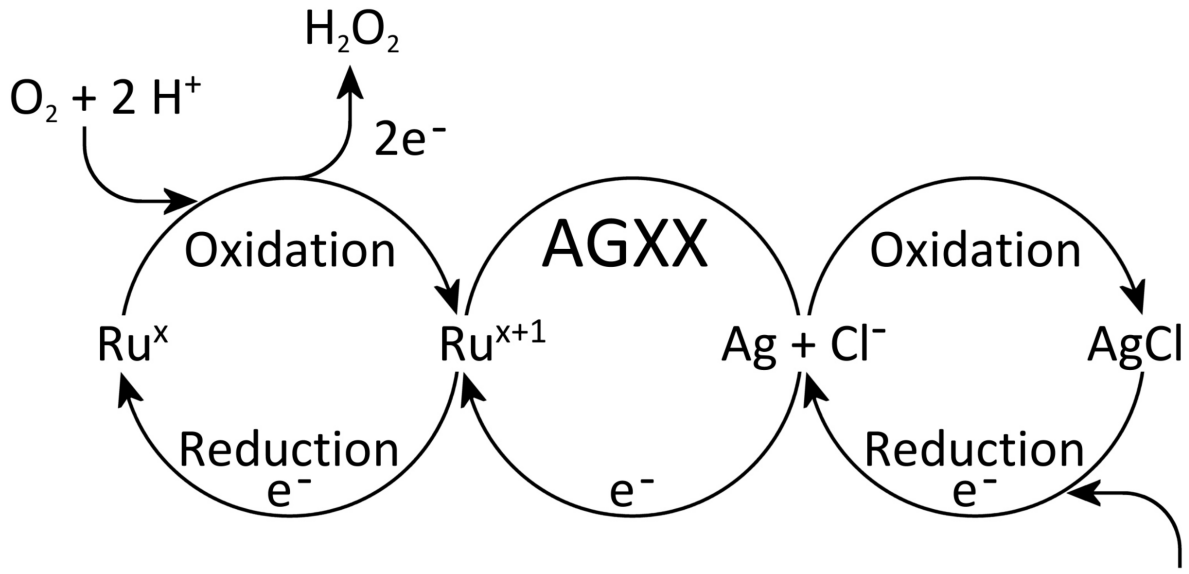


AGXX®

- **Contact catalyst**
- **Ag** and **Ru** clusters form **microelectrodes**
- **Microbes are oxidised, O_2 is reduced to ROS**

→ROS cause cell damage / cell death

→AGXX inhibits growth/ kills germs



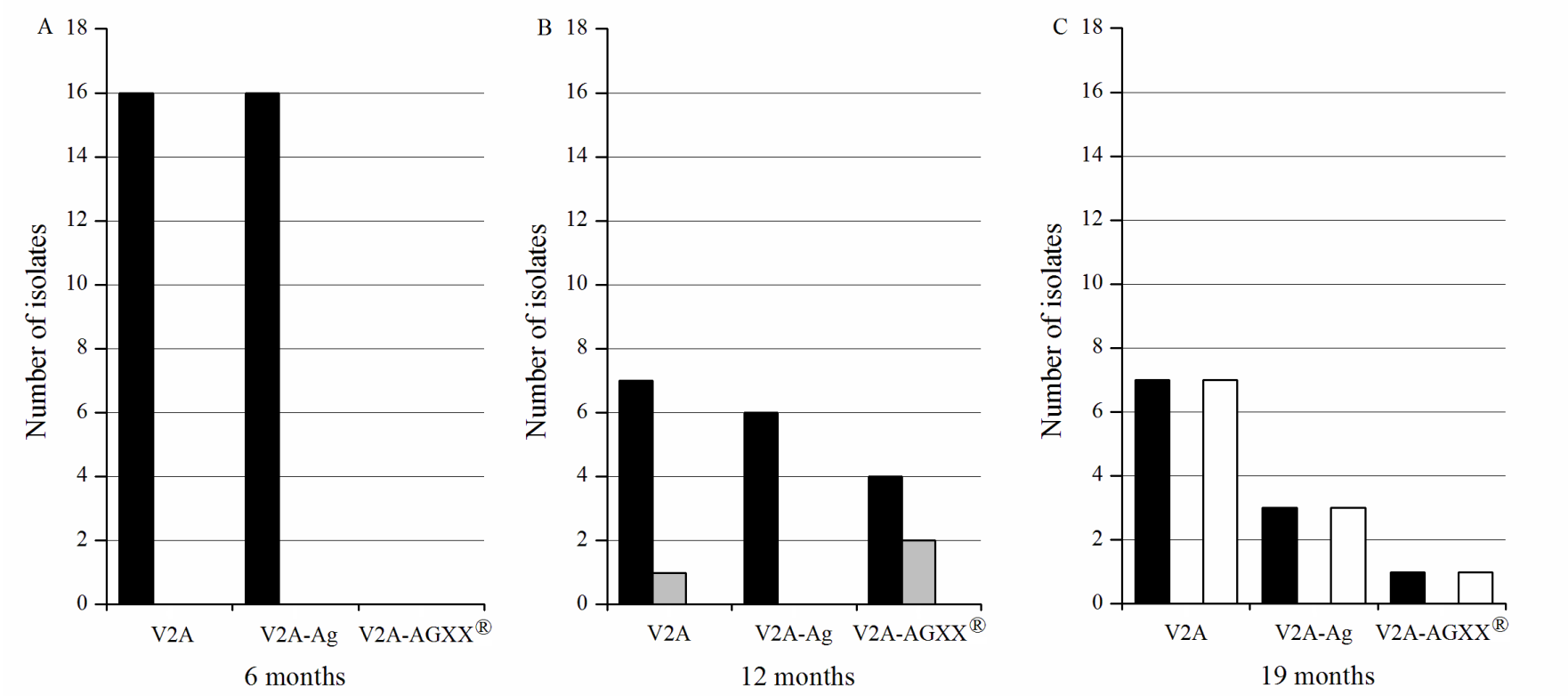
Clauss-Lendzian et al., 2018

Most Important Results

Ankita Vaishampayan, PhD

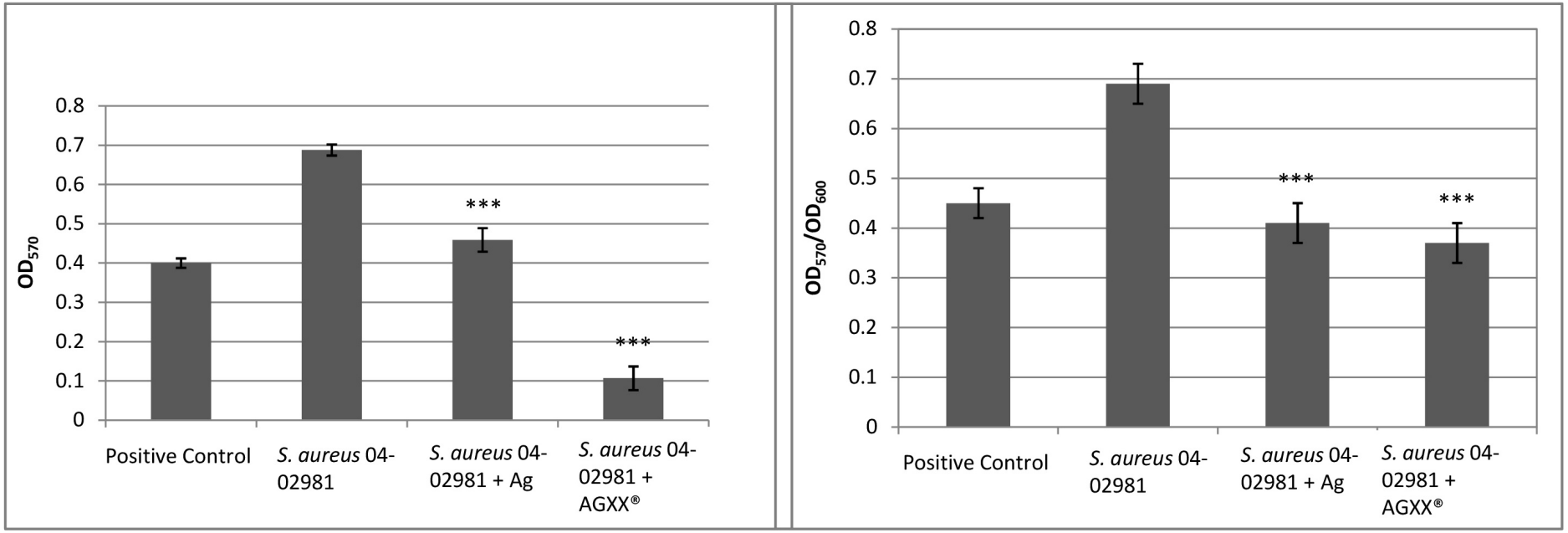
Bacterial Load on ISS Was Reduced by 80%

Black: *Staphylococcus* spp.; gray: *E. faecalis*; white: *B. cereus*



Sobisch et al., 2019

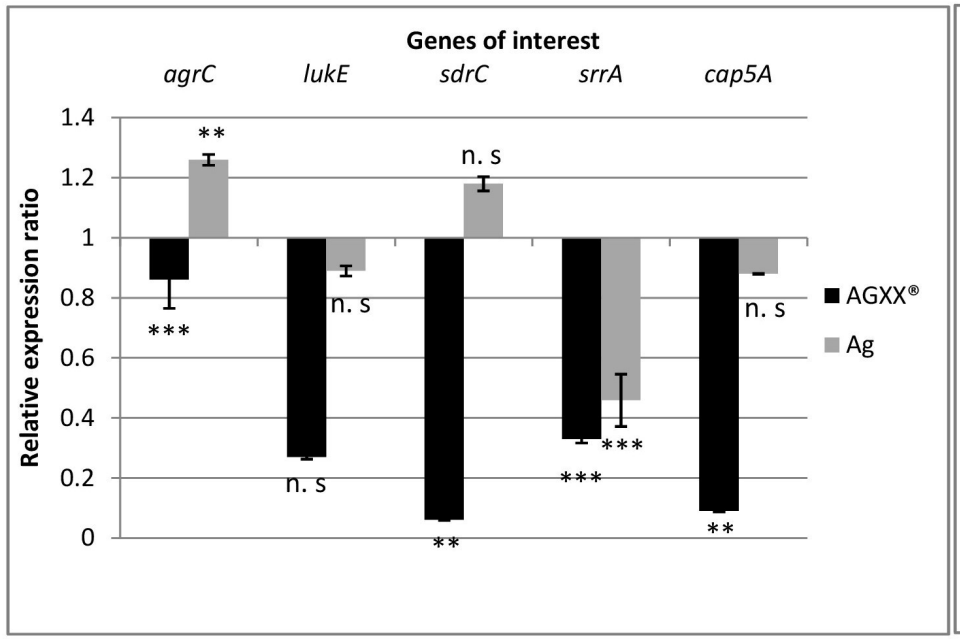
AGXX Strongly Reduces Biofilm Formation of MRSA



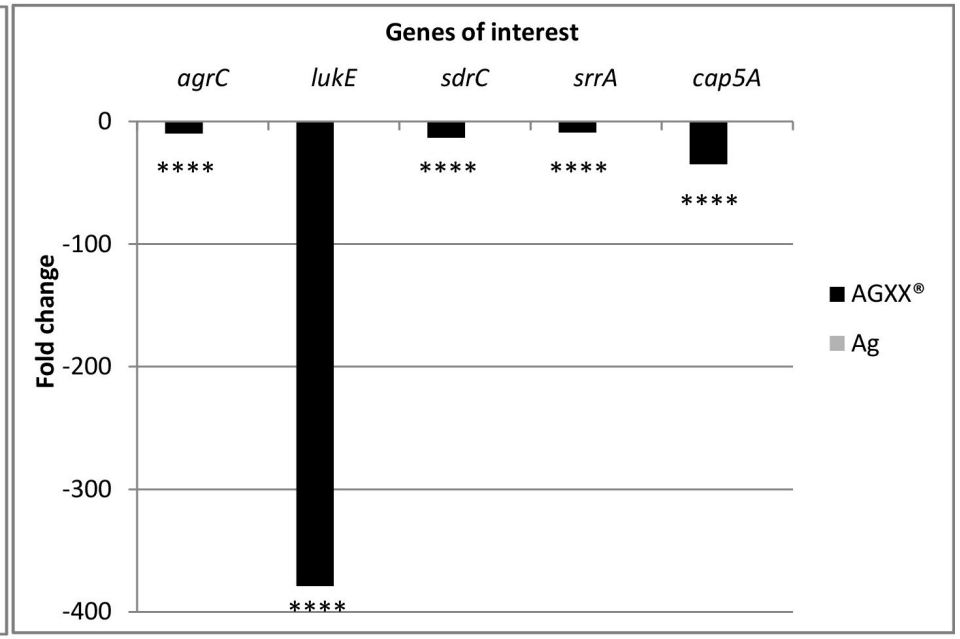
1A **1B**

Vaishampayan et al., 2018

AGXX Reduces Expression of Virulence and Biofilm Genes



6A



6B

Vaishampayan et al., 2018

SIRIUS: 4 Month Isolation Experiment in Moscow

Daniela Wischer, PhD

SIRIUS-2019: International Isolation Study

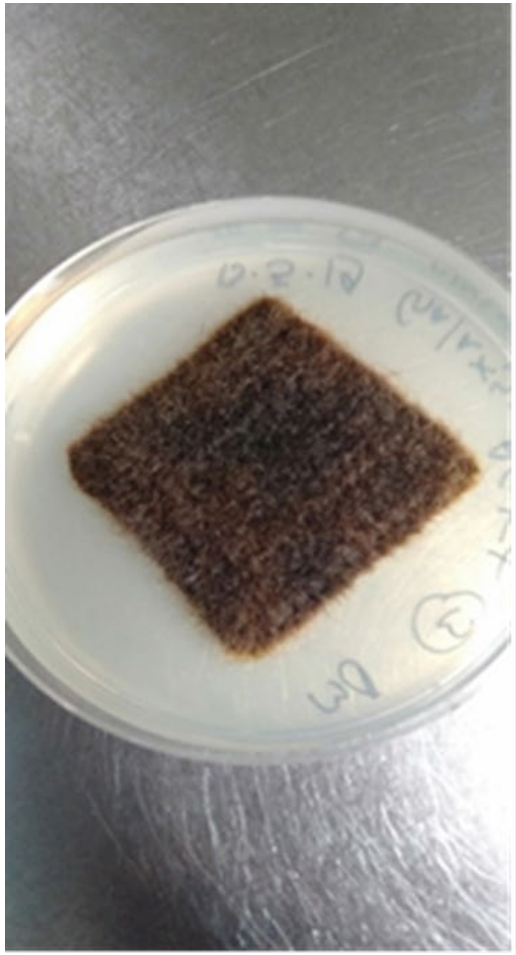
- Crew isolated in Experimental Complex (IBMP, Moscow) for 4 months

AGXX and GOX Exposure in SIRIUS Fitness Room

Approach

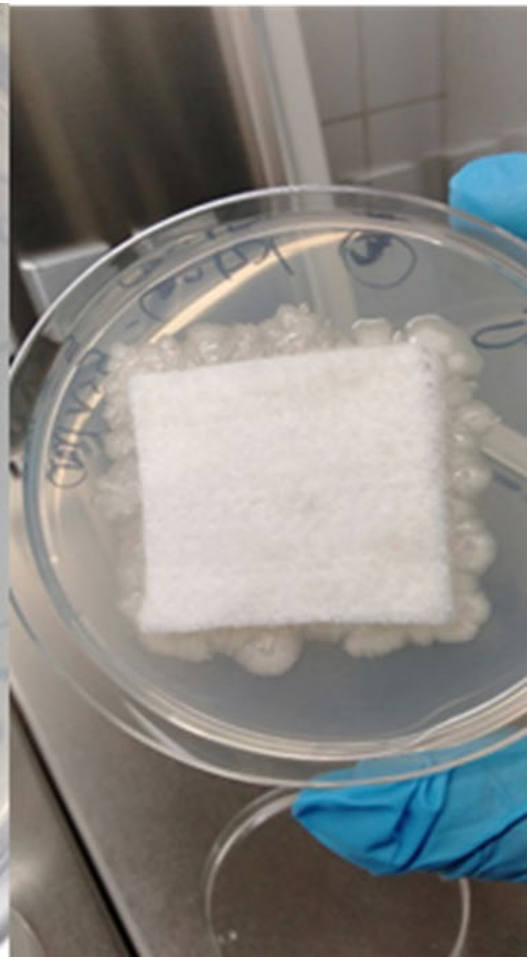
- Exposure of AGXX and GOX aboard SIRIUS-2019
- Control experiment in non-isolated environment
- Analyses of bacterial communities from the materials after 1, 2 and 4 months
- Cultivation-based analyses and 16S rRNA gene amplicon sequencing
- Medically relevant isolates were characterised:
  - antibiotic resistance profile
  - biofilm formation
  - plasmid content/transfer potential

Growth Inhibition by Antimicrobials



AGXX- fleece

GOX-fleece



Fleece

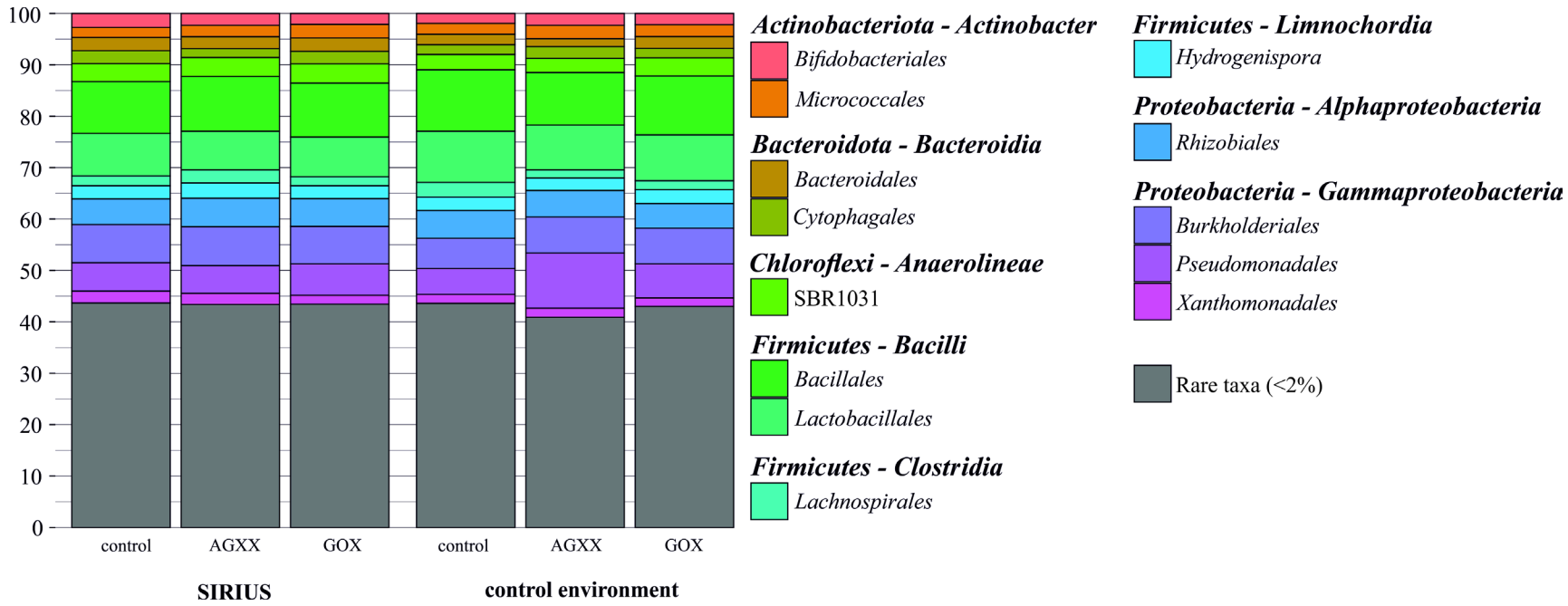
Cultured Microbial Communities

- Dominance of *Staphylococcus* spp.
- Several opportunistic pathogens
- High biofilm formation capacity
- Largely MDR
- No community shift over time
  or with materials

- Diverse environmental bacteria
- Fewer potential pathogens
- Less antibiotic-resistant

16S rRNA Gene Amplicons

- Isolates are not the dominant taxa
- Highly similar communities in both environments
- *Firmicutes*, *Proteobacteria* and *Actinobacteria* > 90%
- *Staphylococcus* sequences comprise only 0.1 – 0.4%



Wischer et al., 2020

Summary SIRIUS 4 Months Study

- Biofilm-forming, human-derived Staphylococci, opportunistic pathogens, dominate SIRIUS-2019 cultured community
- No resistance to last-resort antibiotics
- Few isolates with large plasmids
- Microbial community stable over 4 months
- 16S rRNA gene amplicons suggest bacterial communities are not dominated by *Staphylococci*

Alternative Experiments to SIRIUS 2022 Study (8 Months)

Experimental Procedures (ISO 22196:2011 with Modifications)

Desiccator with antimicrobial materials adjusted to ≥90% relative humidity, materials preincubated to enhance wetting

2 x 2 cm test and control materials

Test strains inoculated during exponential growth (10^9 CFU/mL)

Incubation at 35°C at ≥90% relative humidity

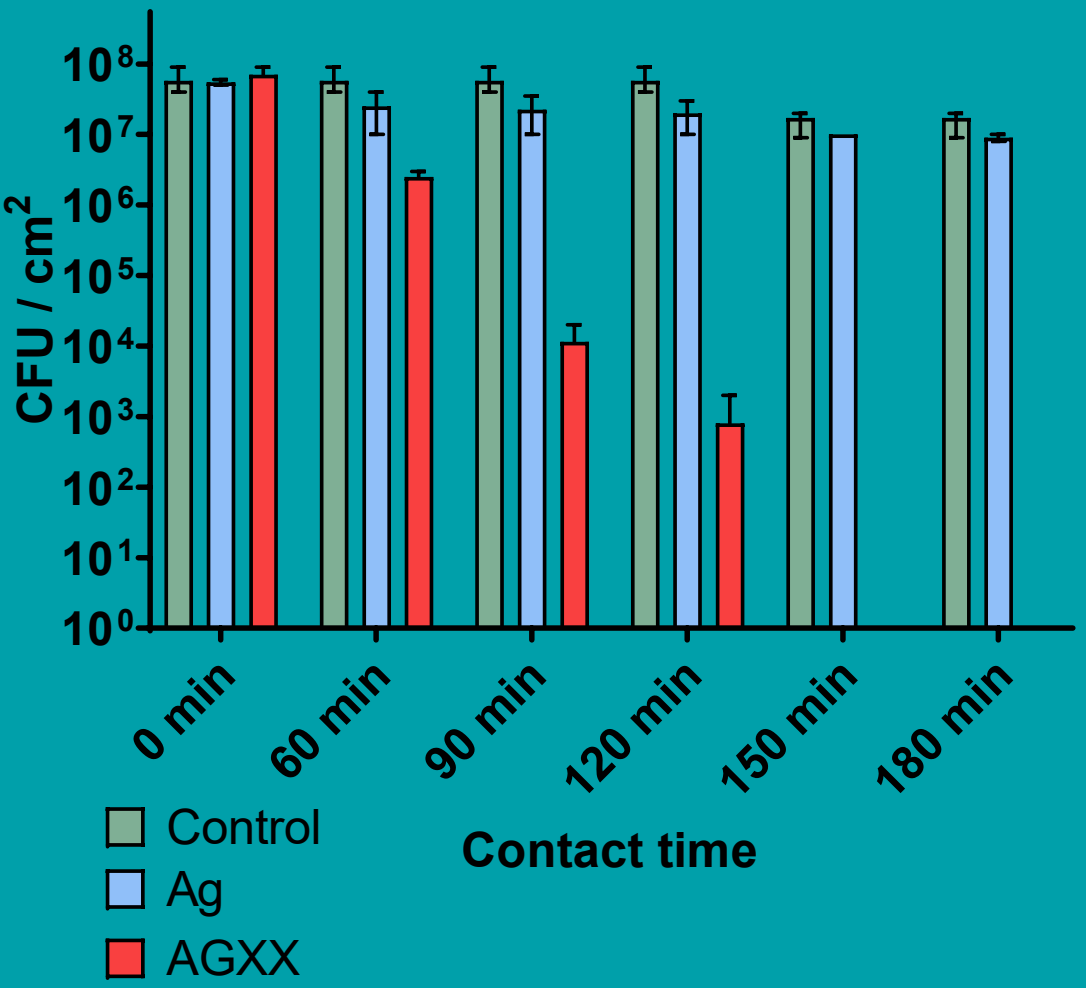
70 µL samples were taken at t= 0, 120, 180 min, and 24 h

Bacterial survival determined by drop plating of dilutions on LB agar

Incubation for 16 h at 37°C

Survival rate determined as CFU/ cm^2 material

Survival of *E.coli* DSM 682 - High Cell Load



5 log reduction in 2 hours

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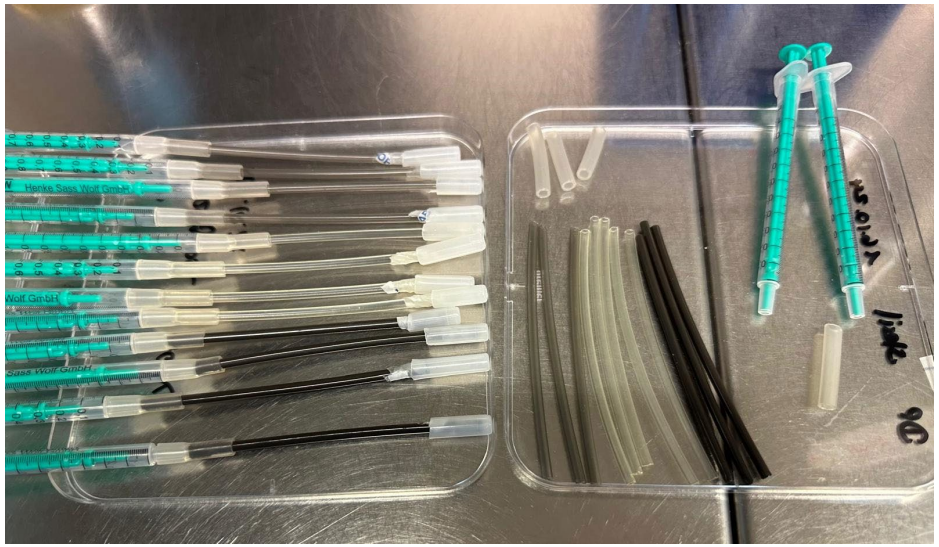
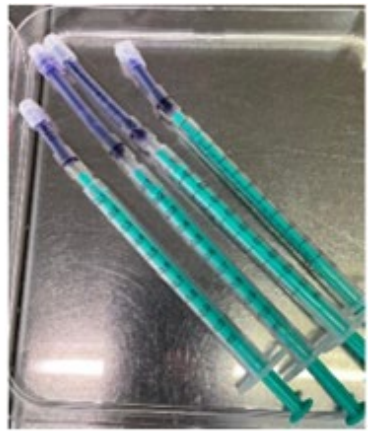
AGXX-antimicrobial activity in simulated dental care units

Dominique Pütz

Polyamide tubes with 0.1% and 1% AGXX



Test organisms: ***Pseudomonas aeruginosa, Legionella anisa***



CONCLUSIONS

- AGXX reduces biofilm formation and consequently antibiotic resistance transfer
- AGXX has high antibacterial activity against Gram+ and Gram- bacteria
- AGXX demonstrated 8 log reduction of *E. coli* in 150 min
- Antimicrobial activity of AGXX is faster than that of Ag
- The higher the ruthenium concentration in AGXX the higher the log reduction of the pathogen

THANK YOU

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DLR

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