Smart Antimicrobial Technologies for a Healthy Environment

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SENG 工學院 SCHOOL OF ENGINEERING

香港科技大學 THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Motivation

Since 1940, more than 300 new infectious diseases have emerged, and **respiratory illnesses** cause the heaviest toll on humans and the economy.

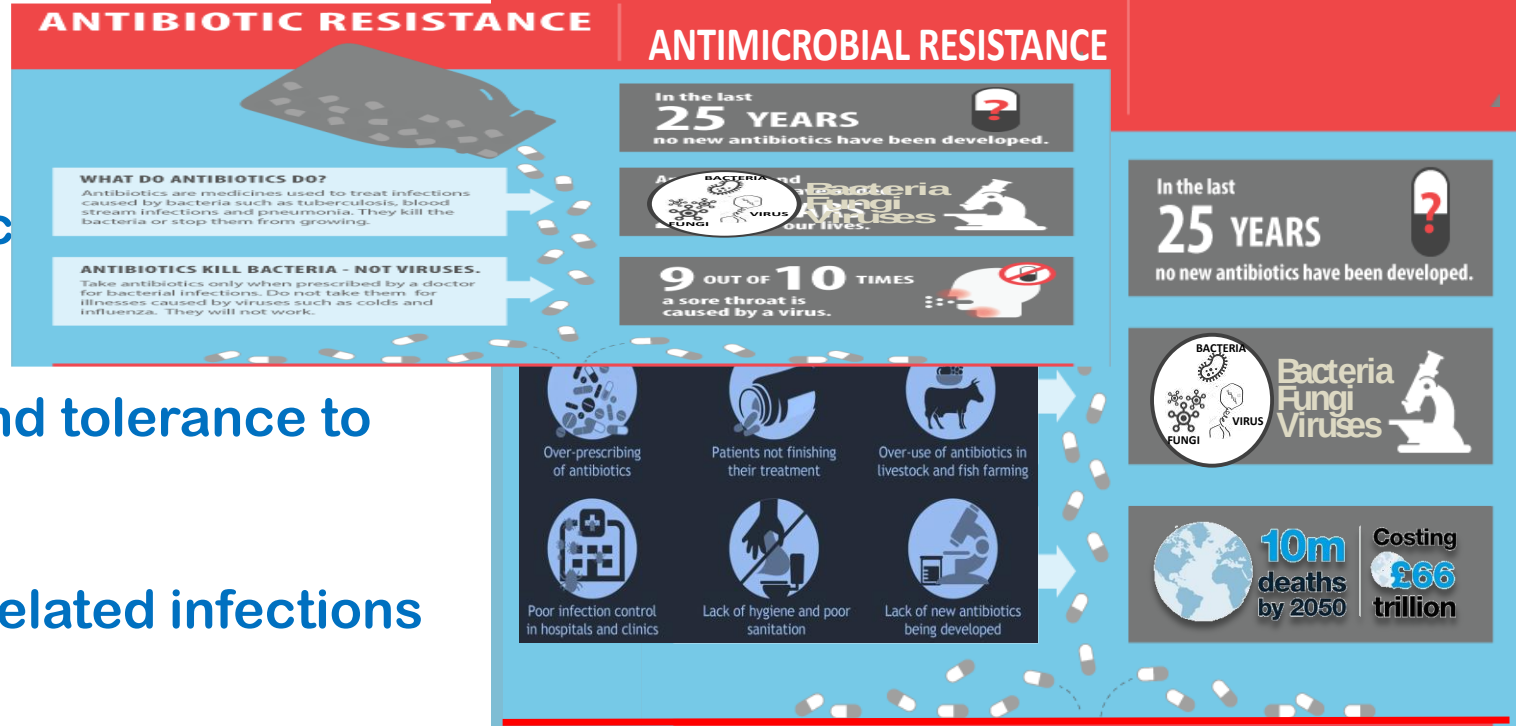
Worldwide prevalence of antimicrobial-resistant (AMR) organisms that are resistant to existing treatments.

Situation

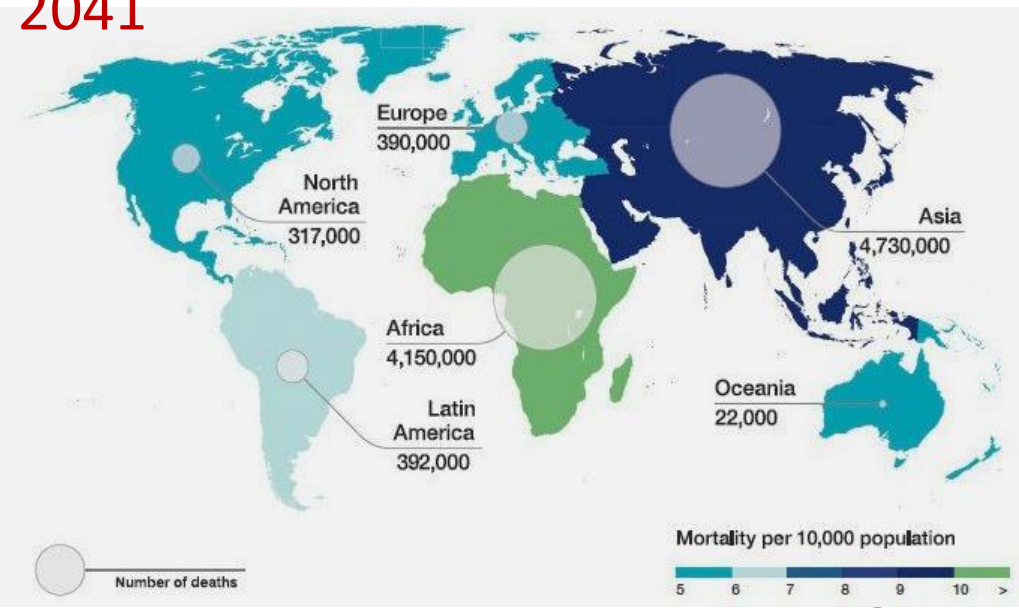
Large-scale infection events occ
interval

Growing microbial resistance and tolerance to existing treatments

Worldwide prevalence of AMR-related infections



2041



Respiratory Pathogens

Viruses

Enveloped viruses
- influenza viruses
- coronaviruses

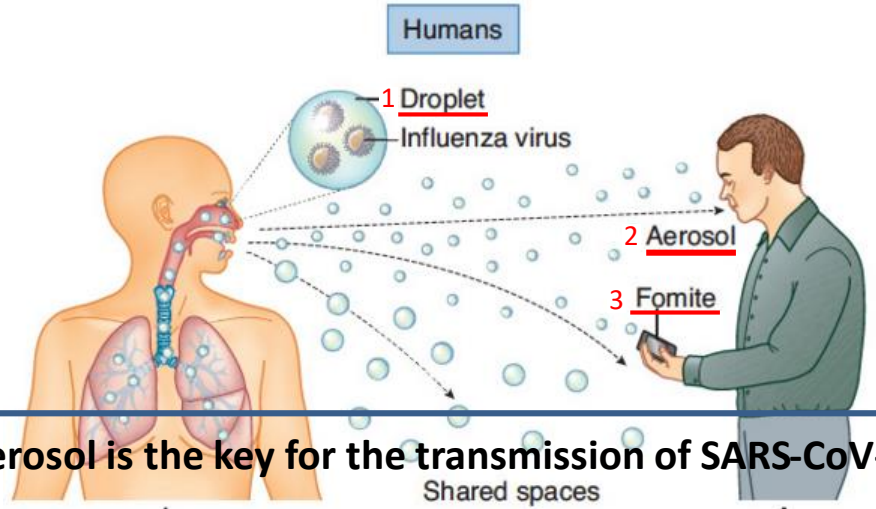
Non-enveloped viruses
- rhinoviruses
- enteroviruses
- adenovirus
- bocavirus

Bacteria/Spores

Infectious dose of around 2-3 viral particles of human influenza virus
Alford RH et al. 1966. Human influenza resulting from aerosol inhalation. Proc. Soc. Exp. Biol. Med.

Stability of SARS-CoV-2 on surfaces
Glass: 2 days
Stainless steel: 4days
Plastic: 4 days
Mask: 7 days !!
Chin et al, 2020, Lancet Microbe

The routes of human-to-human transmission



Aerosol is the key for the transmission of SARS-CoV-2

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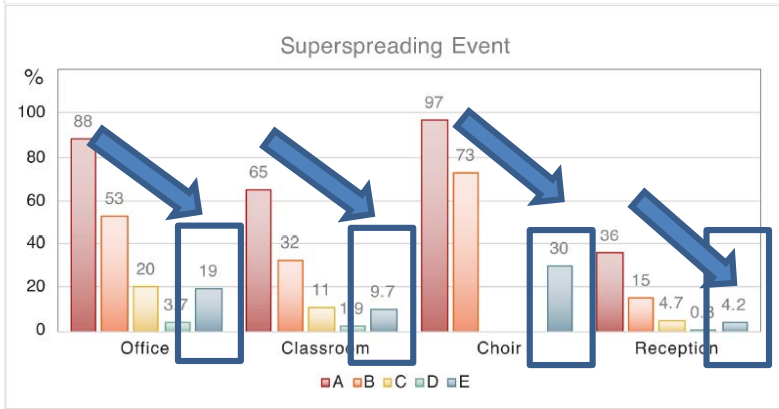


Lelieveld et al. 2020. Int J Environ Res Public Health

Figure 1. Individual risk of a particular person being infected (equivalent to the percentage of the group being infected) in four indoor environments and five scenarios, for standard and superspreading conditions. Scenario A: passive ventilation, no masks. Scenario B: active ventilation with outside air

醫院管理局 HOSPITAL AUTHORITY

衞生防護中心 Centre for Health Protection

基督教靈實協會 HAVEN OF HOPE CHRISTIAN SERVICE 尊重生命 • 改變生命

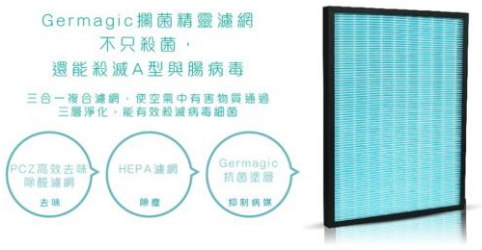
2003 Catalytic air sanitizer Gen 1
> 90 % kill airborne microorganisms

2004 Smart antimicrobial coating Gen 1
kills 90 % bacteria in 30 min

2008 Smart antimicrobial coating Gen 7
> 99 % bacteria in 1 min
> 99 % flu virus in 1 min

2015 field tests in hospital, holistic care facilities, and elderly homes

2018 Smart antimicrobial coating Gen X
> 99.9 % bacteria in 1 min
> 99.9 % flu virus, cold virus, EV71 virus in 1 min
> 98 % MERS-coV
MER-coV
> 99 % spores in 10 min



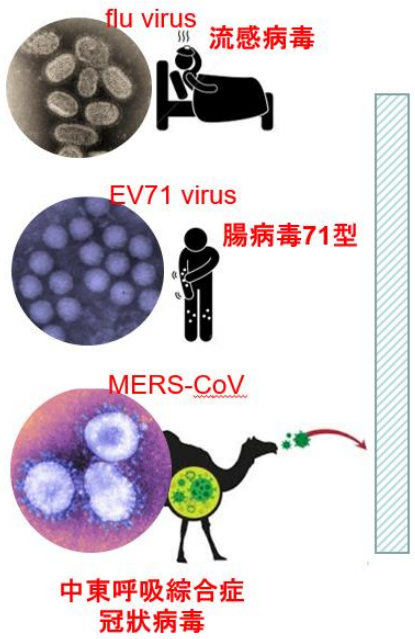
2020 Establishment of the HKUST-CIL Joint Laboratory on Environmental Health Technologies.

2020

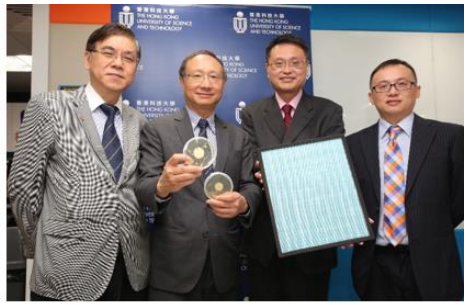
2020

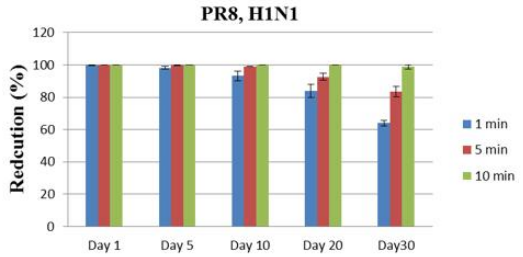
MAP-1
Schools, LTCFs, Clinics, Public Places, Buses, Taxis, Cars, etc.

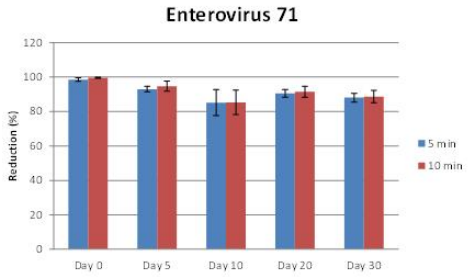
Droplets and Aerosols



- MERS-CoV (EMC strain) 98.8 %
- Influenza A Viruses (A/Puetro Rico/8/1934,H1N1) >99.999%
- Influenza B Virses (B/Lee/1940) >99%
- Hong Kong Flu (A/HK/68,H3N2) >99%
- Enterovirus 71 (EV71) >99%
- H1N1 Swine Flu or Novel Influenza A (A/ Guangdong/ GIRD02/2009,H1N1) >99.9%







GERMAGIC Germicidal Coating

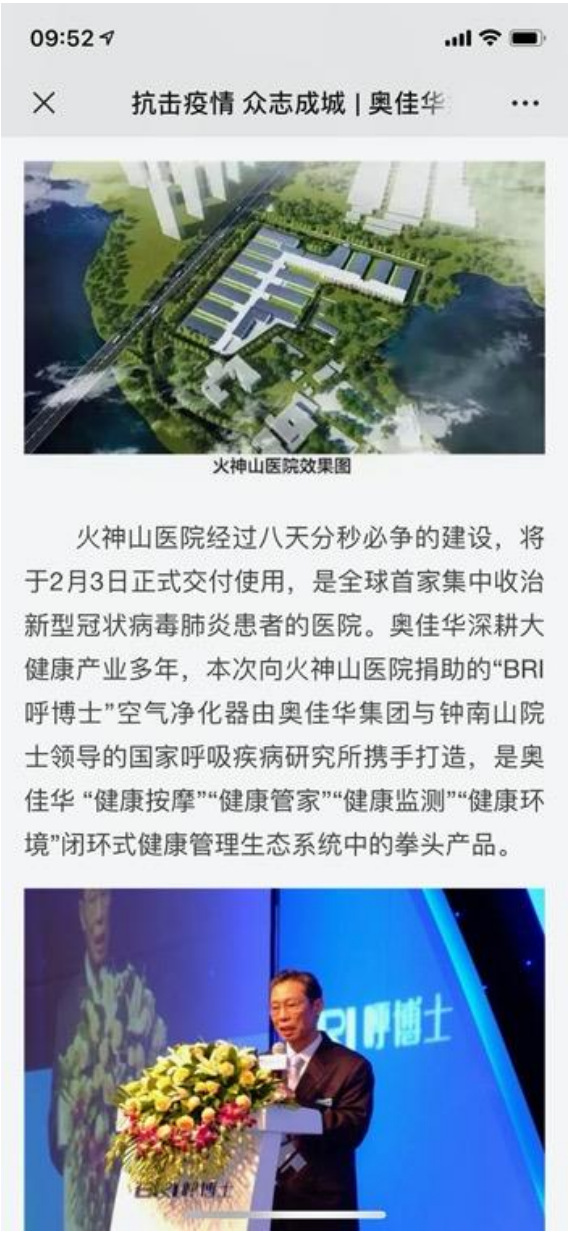
Giabo 捷家伴

三度健康科技 SUNGRUN

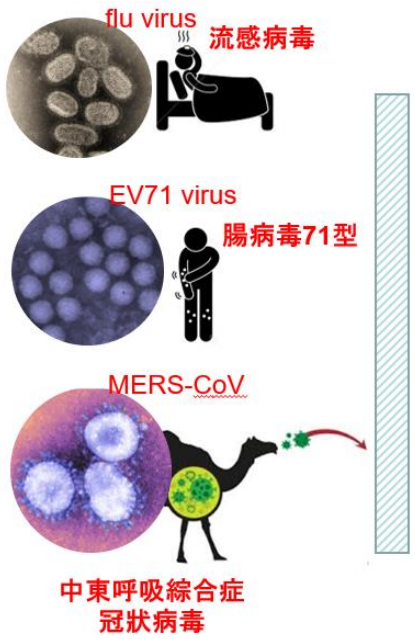
Chiaphua Industries Limited

12

基督教 靈實協會 HAVEN OF HOPE CHRISTIAN SERVICE



HKUST Antimicrobial Filter (PECD)



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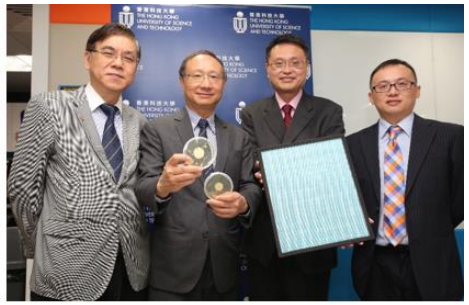

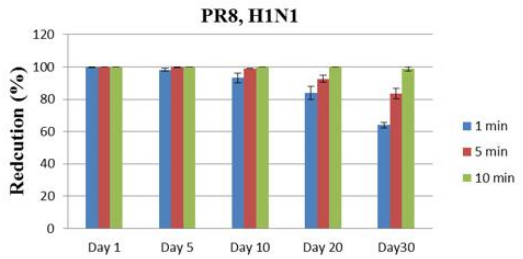

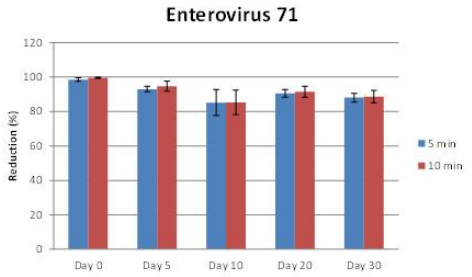

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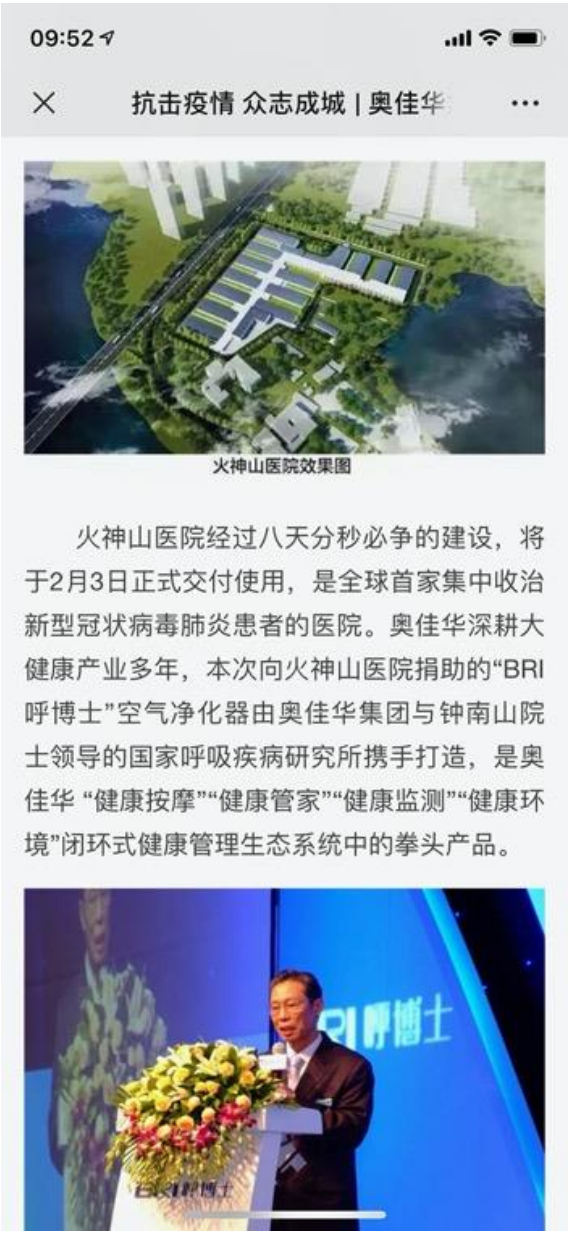
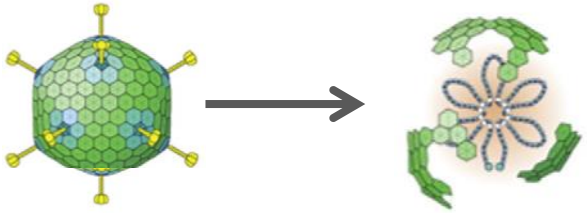
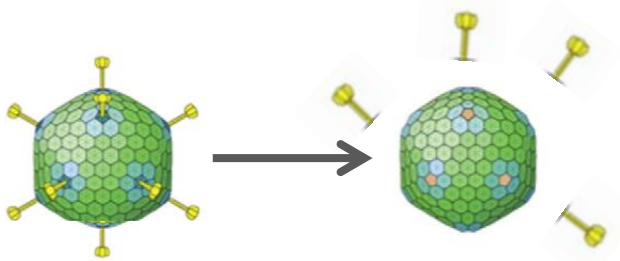


How It Works?

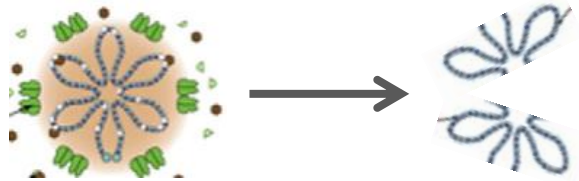
Contact-Killing, Release-Killing, and Anti-adhesion



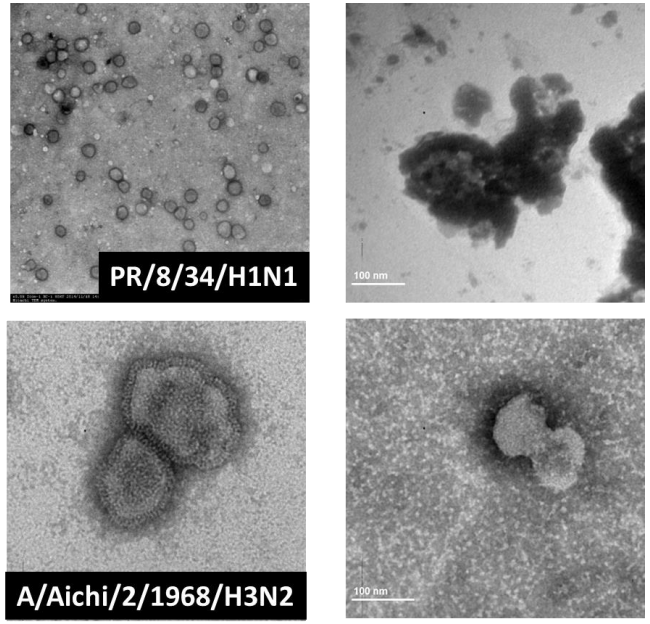
Physically Damage the Viral Capsid

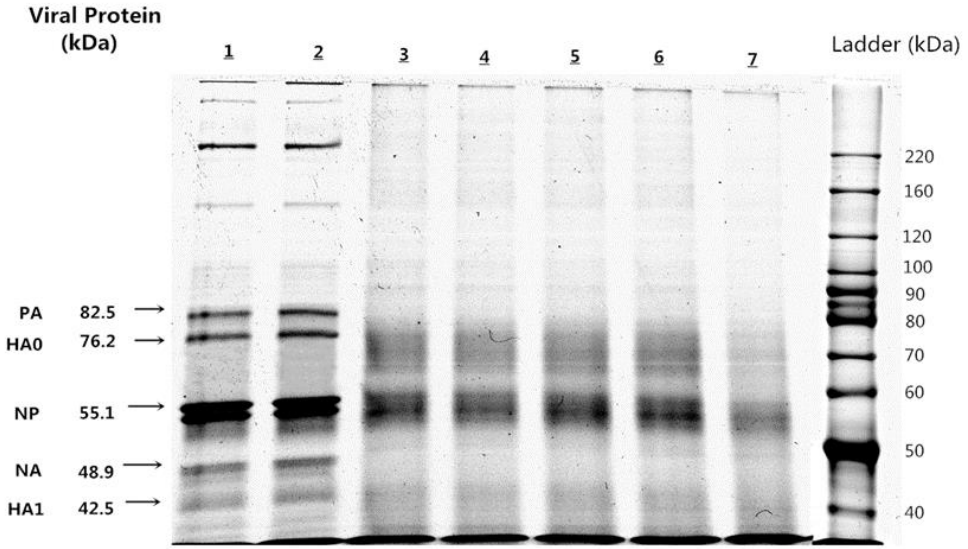


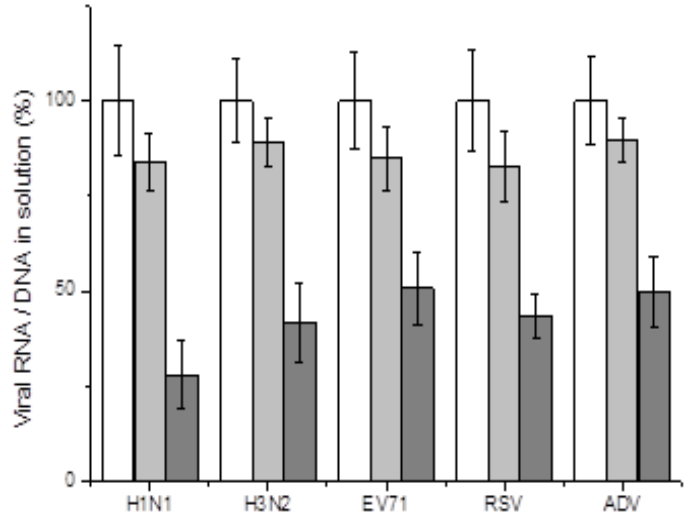
Disassemble the Viral Spikes



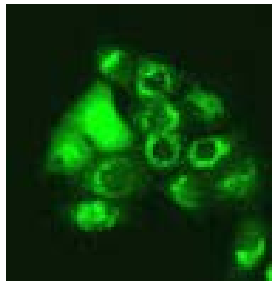
Breaks the DNA/RNA

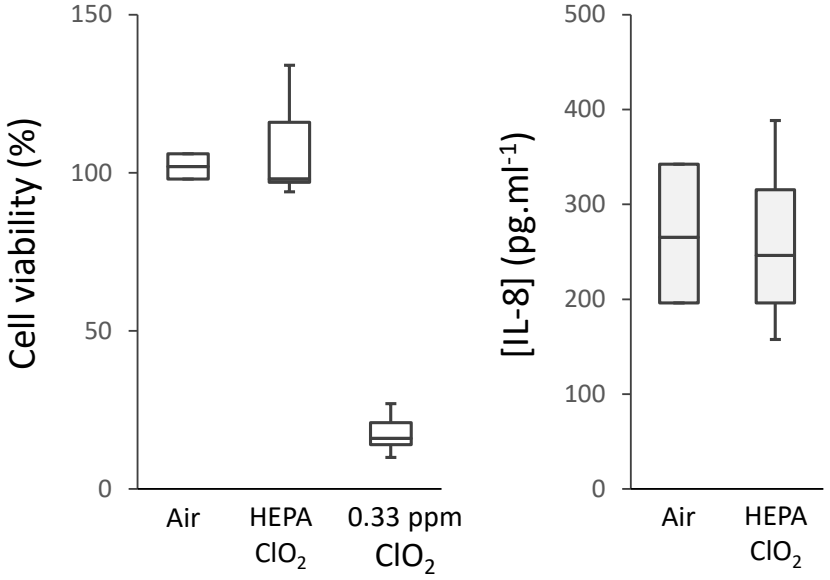






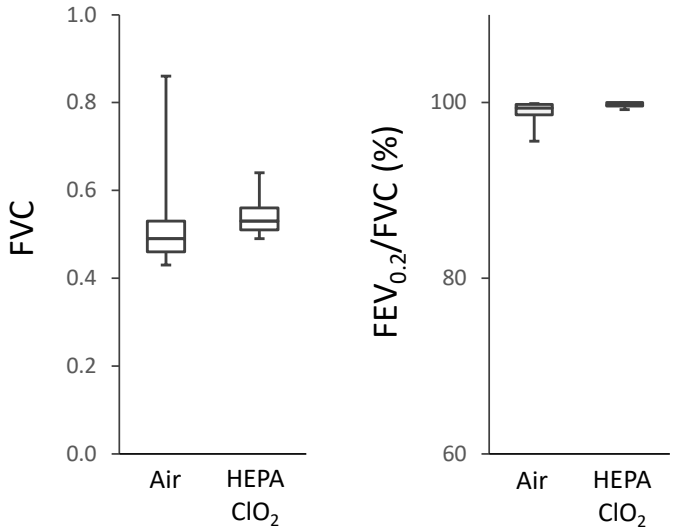
Is it Safe?

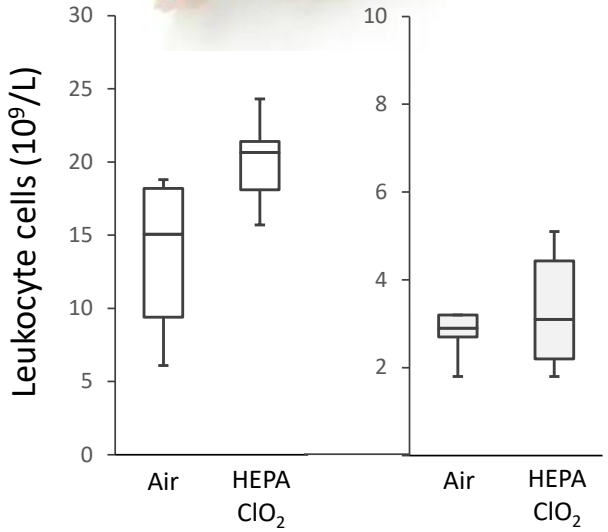


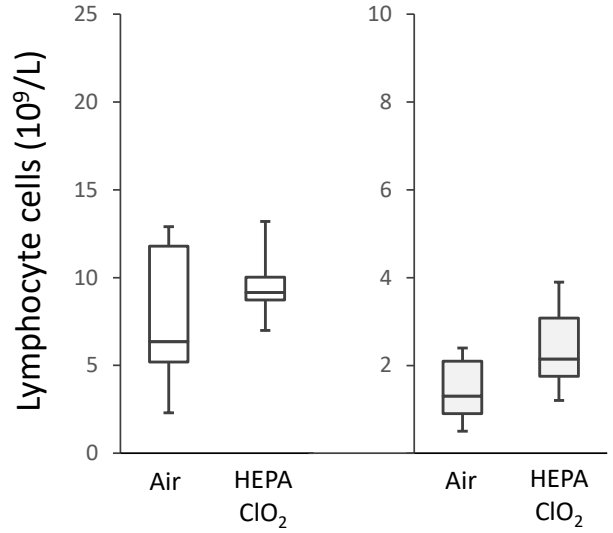


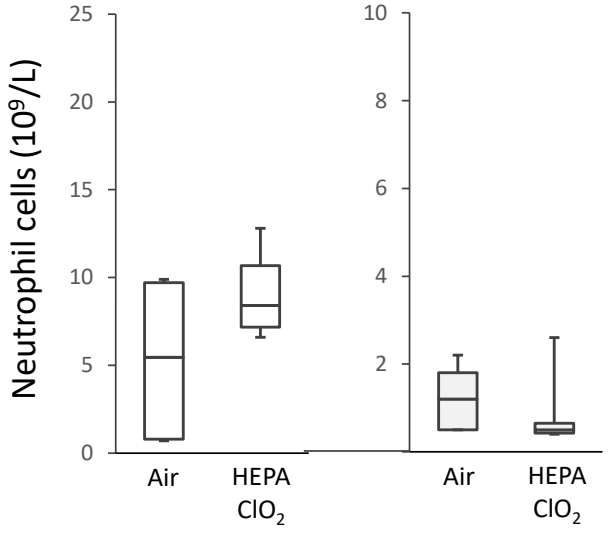
Human Lung Cells

Animal Model

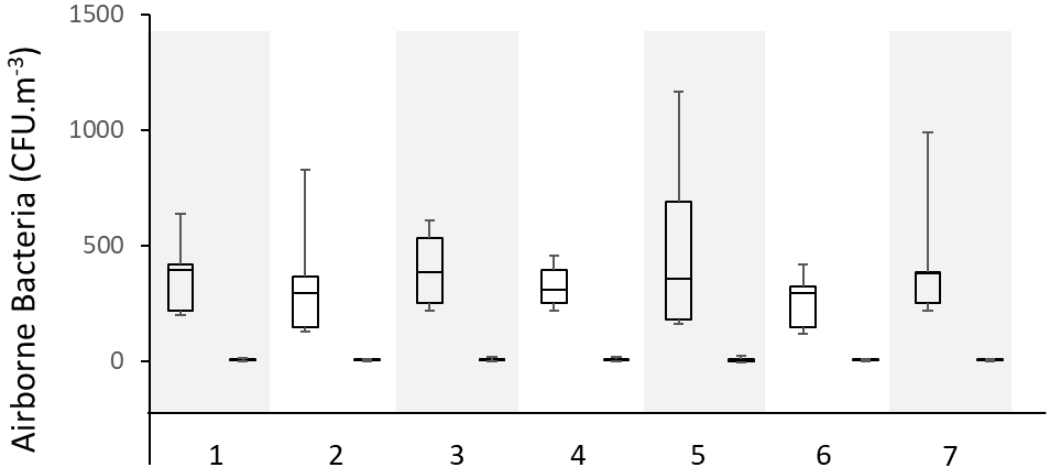


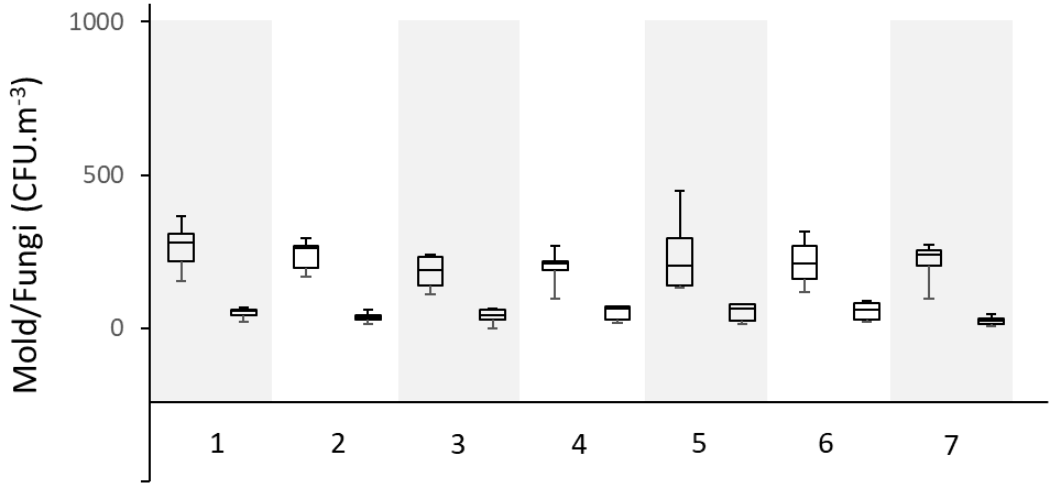


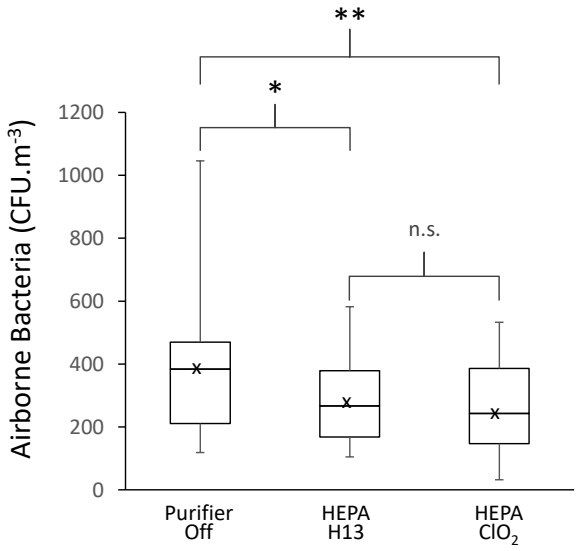


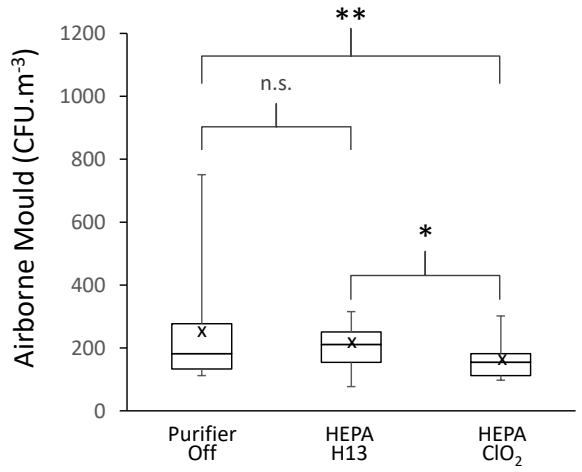


Performance under practical use?



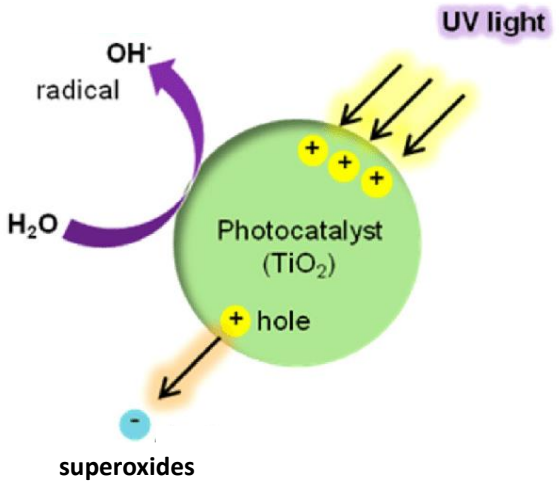






Fomites

PCO and Chelated Compounds



plus

Ag^{+}, Ag^{0} NP
Cu^{2+}, Cu^{0} or CuO NP
Pt^{4+}, Pt^{0} NP

Generates reactive oxygen species

Effective against simple organic molecules

but, produces secondary pollutants

slow to inactivate microbes (> 2 h)

Published in final edited form as:
Mol Cancer Ther. 2009 January ; 8(1): 10–16. doi:10.1158/1535-7163.MCT-08-0840.

Platinum Neurotoxicity Pharmacogenetics

Sarah R. McWhinney[1,2], **Richard M. Goldberg**[2,4], and **Howard L. McLeod**[1,4,*]

Published in final edited form as:
Nanotoxicology. 2018 March ; 12(2): 104–116. doi:10.1080/17435390.2018.1425497.

Silver nanoparticles induce neurotoxicity in a human embryonic stem cell-derived neuron and astrocyte network

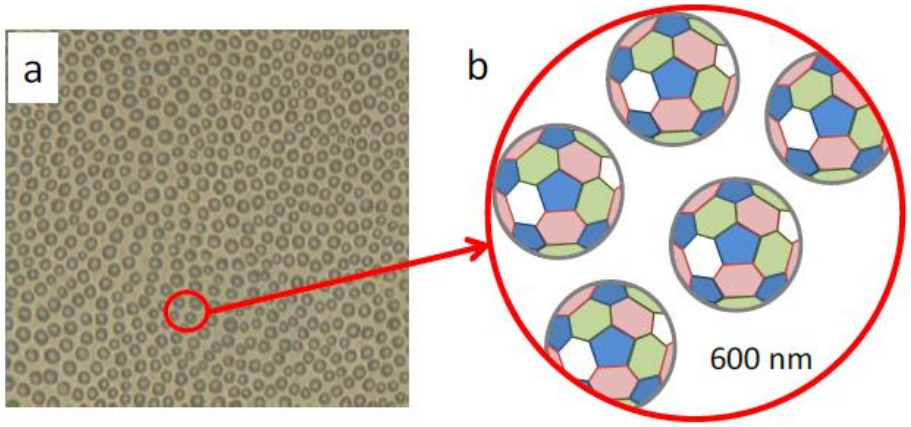
Neza Repar[1,2], **Hao Li**[3,4], **Jose S. Aguilar**[1], **Qingshun Q. Li**[3,4], **Drobne Damjana**[2], and **Yiling Hong**[1,*]

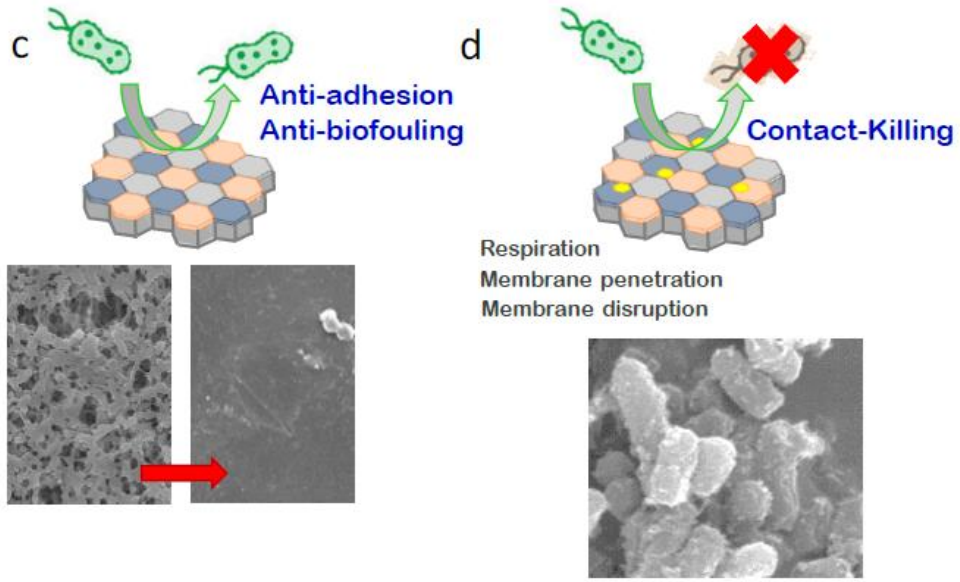
frontiers in Aging Neuroscience
REVIEW
published: 23 January 2018
doi: 10.3389/fnagi.2017.00446

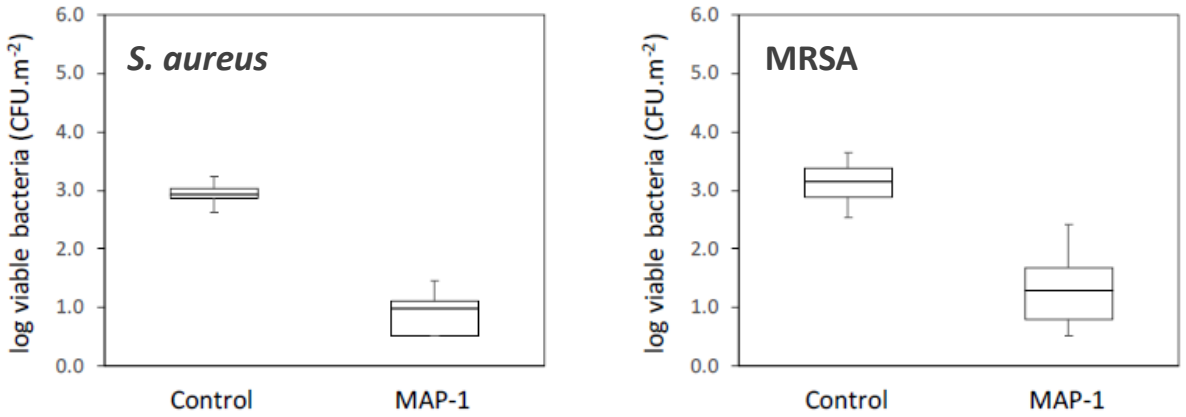
Role of Copper in the Onset of Alzheimer's Disease Compared to Other Metals

Soghra Bagheri[1], *Rosanna Squitti*[2], *Thomas Haertlé*[3,4,5], *Mariacristina Siotto*[6] *and Ali A. Saboury*[3*]

Multilevel Antimicrobial Polymers (MAP-1)







10^5 CFU 60 s contact on MAP-1 coated glasses

Table 1. Bactericidal and sporicidal activities of MAP-1

Bacteria[1]				Spores[2]	
Drug-sensitive		Drug-resistant			
S. aureus	99.1%	MRSA	98.7%	*P. chrysogenum*	99.1%
E. faecalis	98.8%	VRE	98.4%	*C. albicans*	99.4%
P. aeruginosa	96.3%	MRPA	96.2%	*A. niger*	16.0%
A. baumannii	98.5%	MDRA	97.0%		
E. coli	99.6%				

The data are comparisons between uncoated (control) and MAP-1 coated glass slides challenged with [1]10^5 CFU bacteria for 60 s and with 10^5 viable spore particles for 10 min before neutralization, recovery, culture and enumeration following standard procedure.

Multilevel Antimicrobial Polymers (MAP-1)

Killing Difficult to Kill microbes

eurofins

Measles virus	99.990 %	10 min
Mump virus	99.940 %	10 min
Rubella virus	99.900 %	10 min
Feline calicivirus	99.995 %	10 min
Penicillin spores	99.90 %	10 min
Aspergillus spores	99.80 %	10 min

MS2 Phages	99.78 %	10 min

ALG ANALYTICAL LAB GROUP

Human Coronavirus	99.90 %	10 min

MICROBAC®

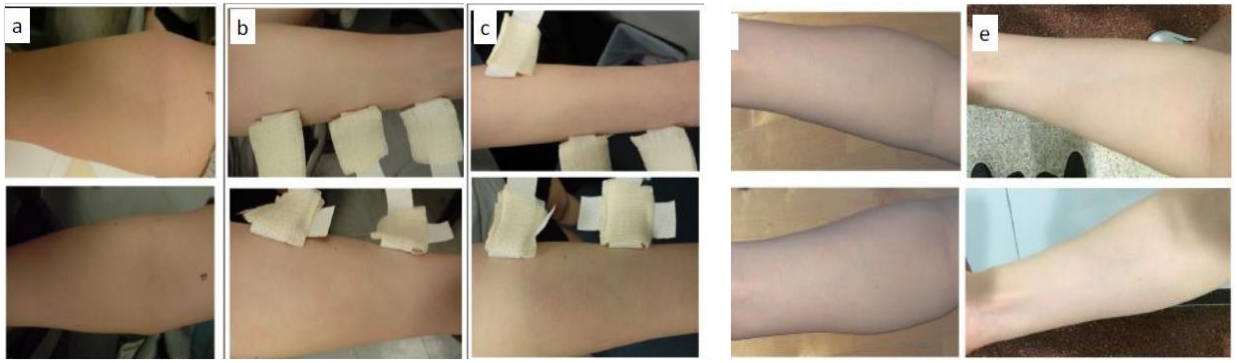
SARS-CoV-2 (COVID-19 virus)	>99.90 %	10 min

MAP-1 Safety

Cell Lines, Animal, and Human

Cell line	Percent Viable Cell (%)		
	1:49 bleach	1:99 bleach	MAP-1
Lung[1]	< 10	50	> 95
Kidney[2]	70	80	> 95
Skin[3]	< 10	80	> 95

[1]A549 human adenocarcinomic alveolal basal epithelial cells; [2]Madin-Darby canine kidney epithelial cells; [3]A431 human epidermoid carcinoma epithelial cells.

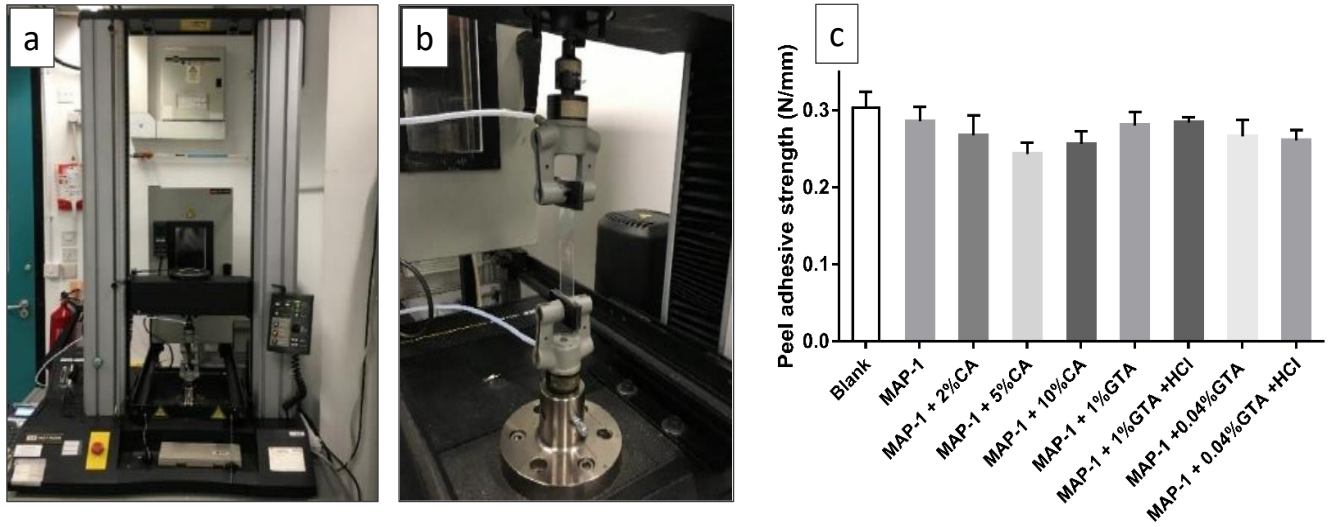


Skin test showing the condition of the volunteer's arms (a) before, (b) after 30 min contact with pads saturated with MAP-1 (upper image) and sterile water (lower image), (c) after 60 min contact with pads saturated with MAP-1 (upper image) and sterile water (lower image), (d) 24 h after exposure to MAP-1 (upper image) and sterile water (lower image), and (e) 48 h after exposure to MAP-1 (upper image) and sterile water (lower image).

受试物对家兔多次完整皮肤刺激试验结果

涂抹天数	动物数（只）	刺激反应积分					
		样品			对照		
		红斑	水肿	总分	红斑	水肿	总分
1	3	0	0	0	0	0	0
2	3	0	0	0	0	0	0
3	3	0	0	0	0	0	0
4	3	0	0	0	0	0	0
5	3	0	0	0	0	0	0
6	3	0	0	0	0	0	0
7	3	0	0	0	0	0	0
8	3	0	0	0	0	0	0
9	3	0	0	0	0	0	0
10	3	0	0	0	0	0	0
11	3	0	0	0	0	0	0
12	3	0	0	0	0	0	0
13	3	0	0	0	0	0	0
14	3	0	0	0	0	0	0
14 天总积分		0					
14 天每只动物积分均值		0					
每天每只动物积分均值		0					

MAP-1 Durable



Pictures of (a) the Instron tensile tester and (b) the tensile module for tape pulling, and (c) plots of the peel adhesive strength for the MAP-1 coatings on glass.

Wiping	Bactericidal (%)		
	64x	128x	500x
Dry cloth	99.98	99.72	99.97
Wet cloth with			
Water	99.88	99.56	99.53
Bleach (1:99)	99.97	99.80	99.77
Dettol (1:40)	99.75	99.63	99.58
Detergent (2%)	n.d.	n.d.	99.77
Alcohol (30%)	n.d.	99.80	99.49
CGW[1] (1:50)	98.71	99.63	98.66

[1]Campbell Green Water
n.d. not done

A consistent peel adhesive strength of 0.3 N/mm compared to typical paints are rated at 9 N/25 mm or 0.36 N/mm.

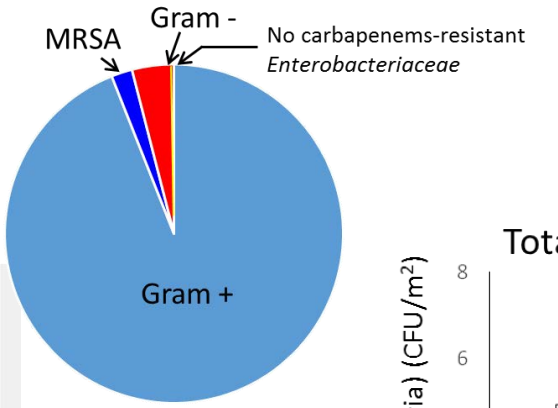
Field Study at Hospital

Dr. Dominic Tsang (Clinical Microbiologists, former HA Chief Infection Officer)
Dr. Christopher Lai (Clinical Microbiologists, former Infection Control Officer
Kowloon Hospital)

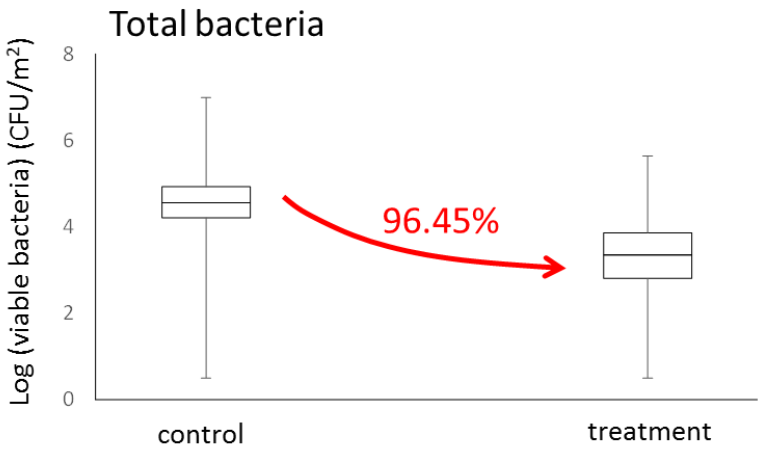
Surface Cleansing/Coating

Hard and soft surfaces
Long-lasting > 30 days
Effective against AMRs

九龍醫院 KOWLOON HOSPITAL

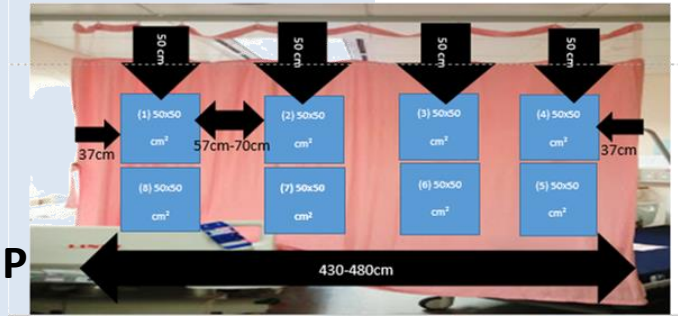


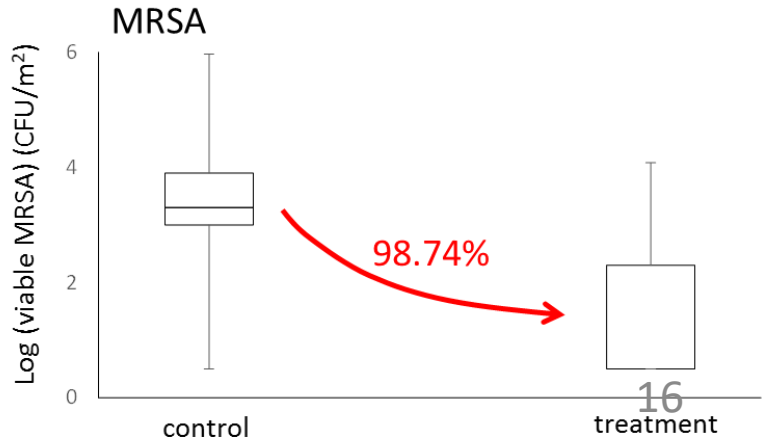
7 months
1824 samples
912 control, 912 treatment



Clinical Trial

Location: KH Rehabilitation Ward
Male and female cubicles (3b)
Sampling:
Once a week for 3 weeks
9:00 am to 12:00 nn
8 samples per curtain each (50 x 50 cm²)





Field Study at Hospital

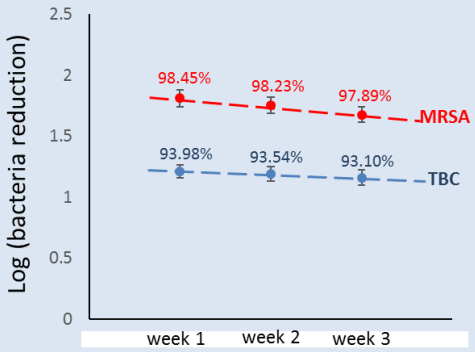
Dr. Dominic Tsang (Clinical Microbiologists, former HA Chief Infection Officer)
Dr. Christopher Lai (Clinical Microbiologists, former Infection Control Officer
Kowloon Hospital)

Surface Cleansing/Coating

Hard and soft surfaces
Long-lasting > 30 days
Effective against AMRs

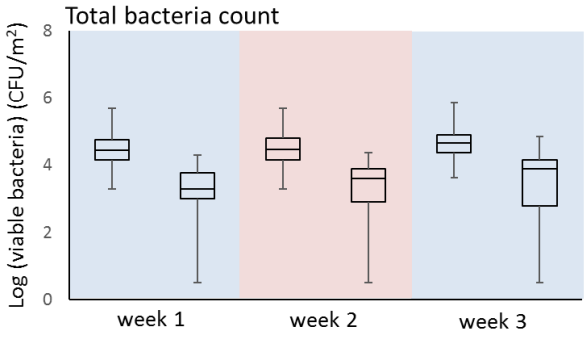
九龍醫院 KOWLOON HOSPITAL

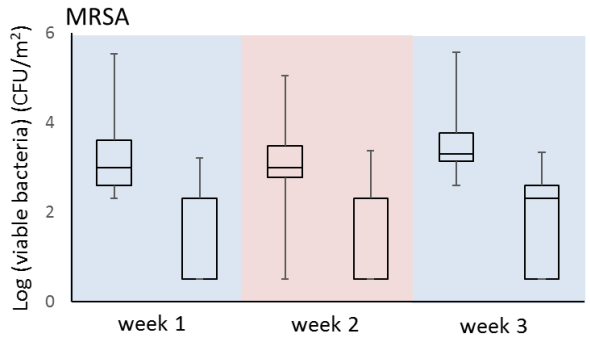
Duration



Data extrapolation indicates that the coating can maintain above 70 % reduction:

TBC	**27 weeks**
MRSA	**20 weeks**





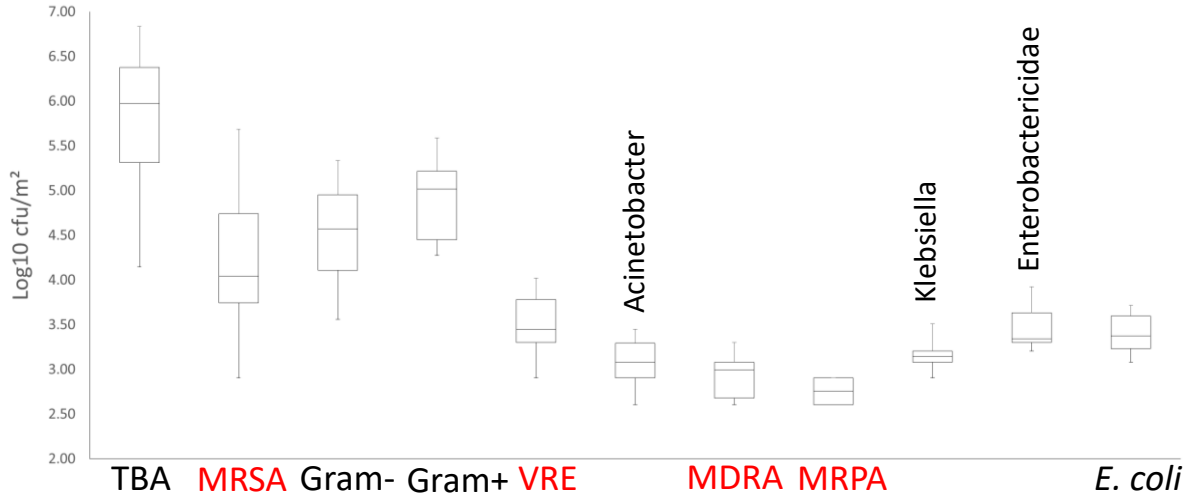
Field Study at Long-term Care

Dr. Ching-Choi Lam (HOHCS)

Antimicrobial Fabric Softener

Easy to use
Tolerate high temperature drying/ironing
Lon sting > 7 days
E against AMRs

SST/015/20GP



基督教 靈實協會 HAVEN OF HOPE CHRISTIAN SERVICE

Clinical Trial

Location: 3rd and 4th Floor of
Haven of Hope Woo Ping Care & Attention Home

6 months

Sample size: 258 (calculated in results of pilot study)

Sample collected: 272 from 94 bedsheets

Sampling:

Once a week for 4 weeks

9:00 am to 12:00 nn

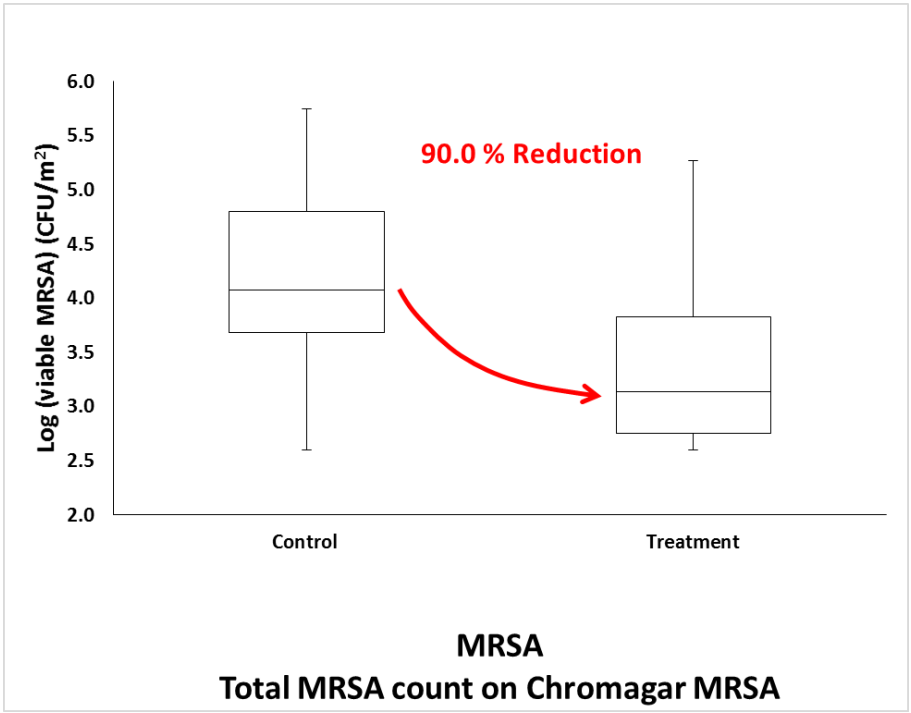
3 samples per bedsheet each (50 x 50 cm^2)

Field Study at Long-term Care

Dr. Ching-Choi Lam (HOHCS)

Antimicrobial Fabric Softener

Easy to use
Tolerate high temperature drying/ironing
Lon[illegible]sting > 7 days
E[illegible] against AMRs



MRSA
Total MRSA count on Chromagar MRSA

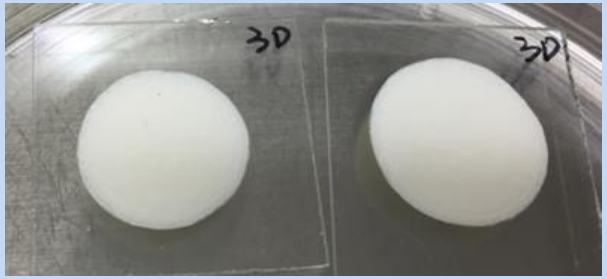
MAP-1 in Coatings

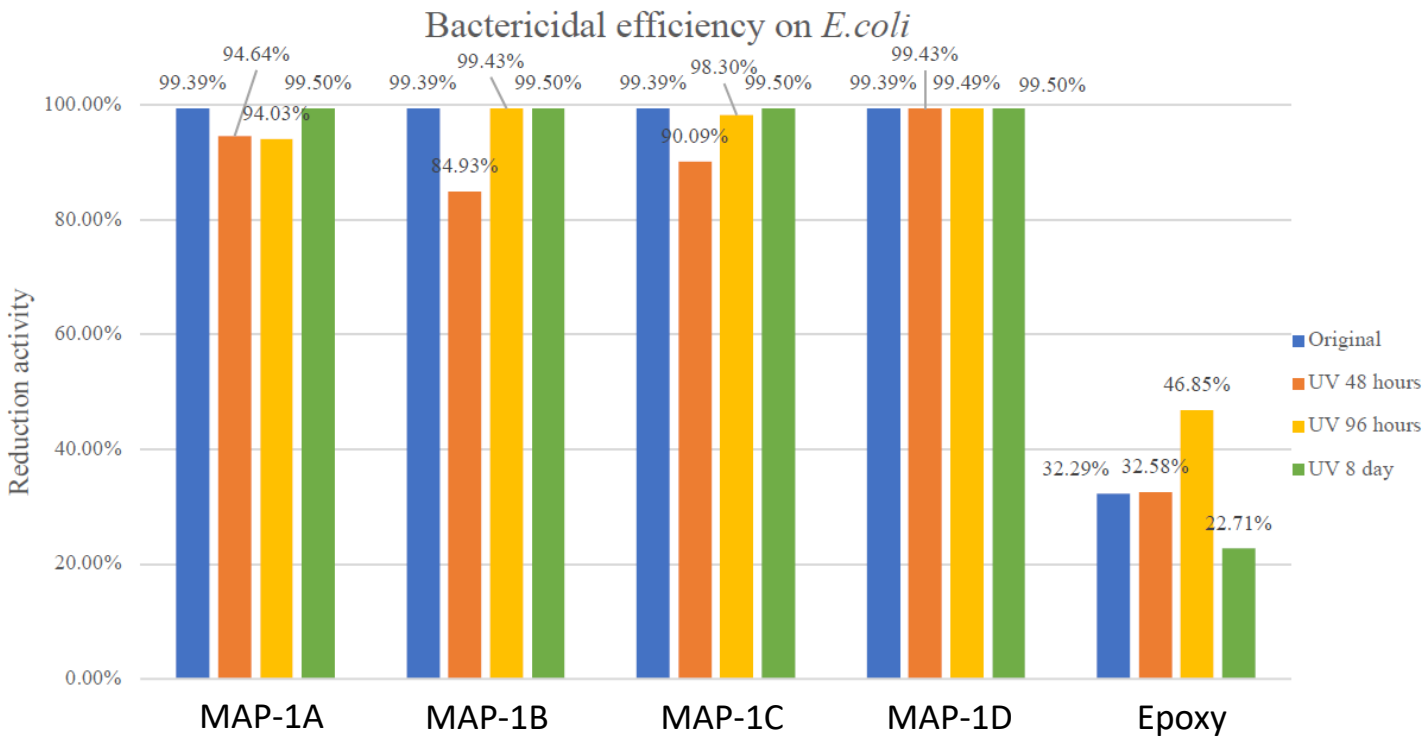
Ms. Annie OY Chan (ME/EM, WSD)
Mr. Brad KH Cheng (ME/EM, WSD)

水務署
Water Supplies Department

Epoxy Coating

Anti-biofouling
Anti-biofilm
Prevent water contamination
Lower pumping cost





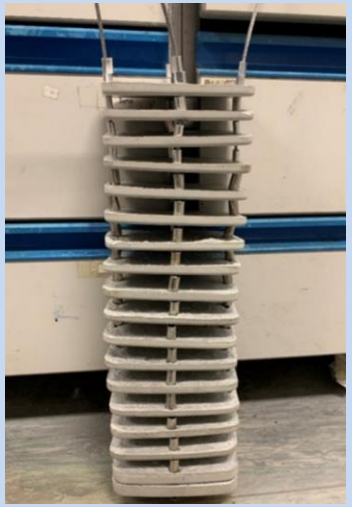
ITB
TCBV Ref: TC17/043

MAP-1 in Coatings

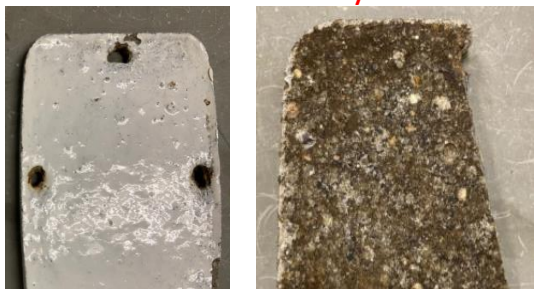
Mr. Saul CM Chan (CE, MS, DSD) Mr. Kenneth KT Shek (CE, MN, DSD)
Mr. Matthew MT Yui (E/A2, DSD) Mr. Maxwell WF Poon (E/A3, MSD, DSD)

Concrete Coating

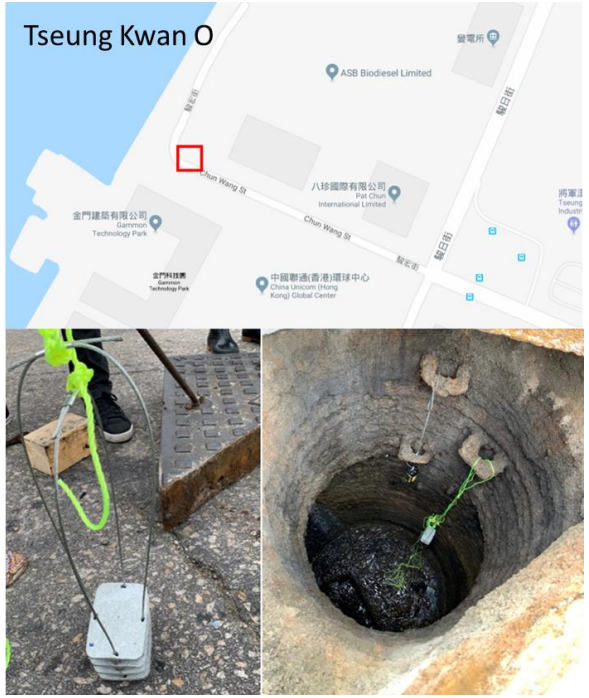
Anti-biofouling
Anti-biofilm
Prevent biofilm growth
Prevent corrosion



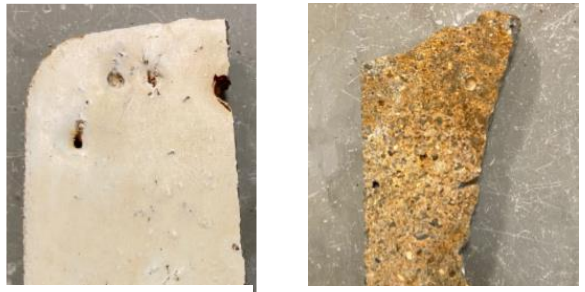
After 270 days



with coating without coating

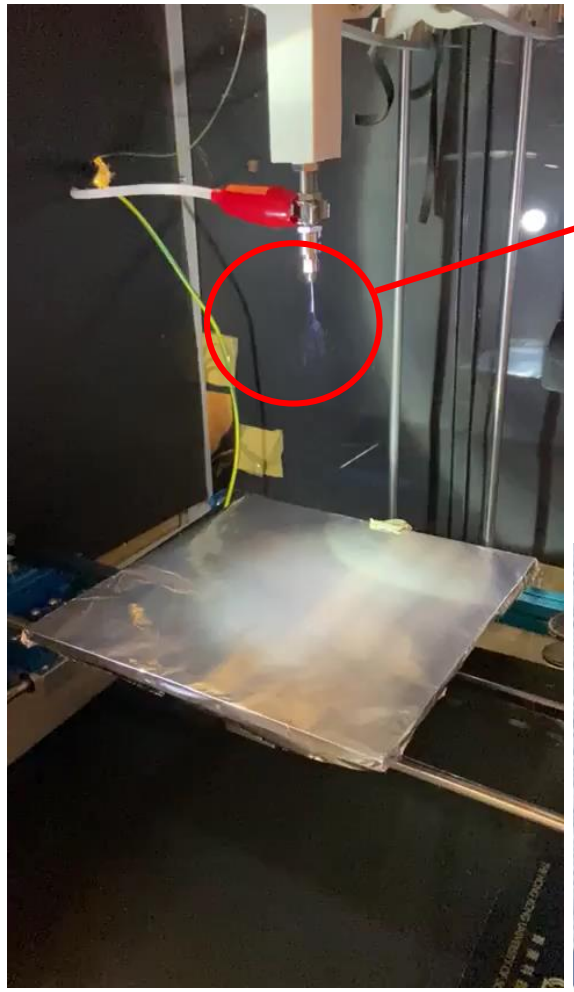


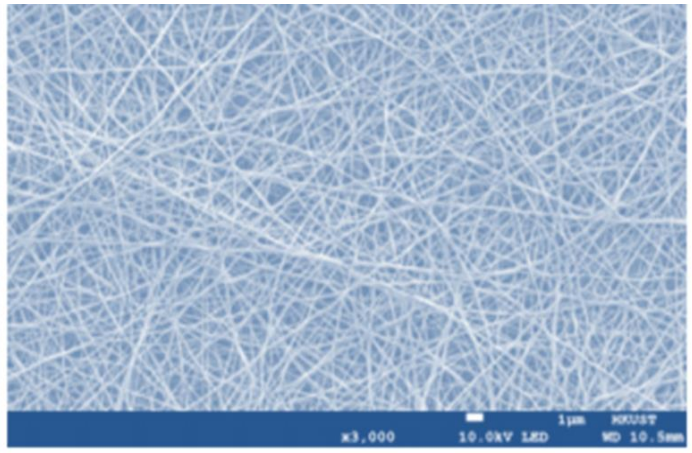
After 90 days

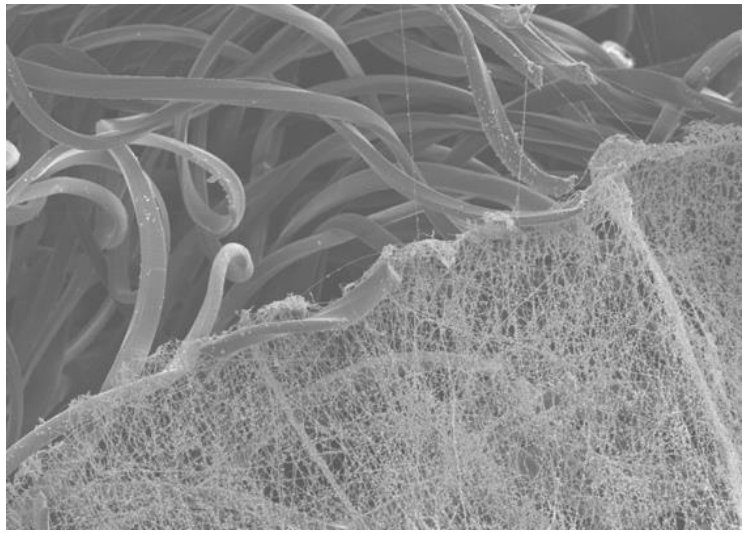


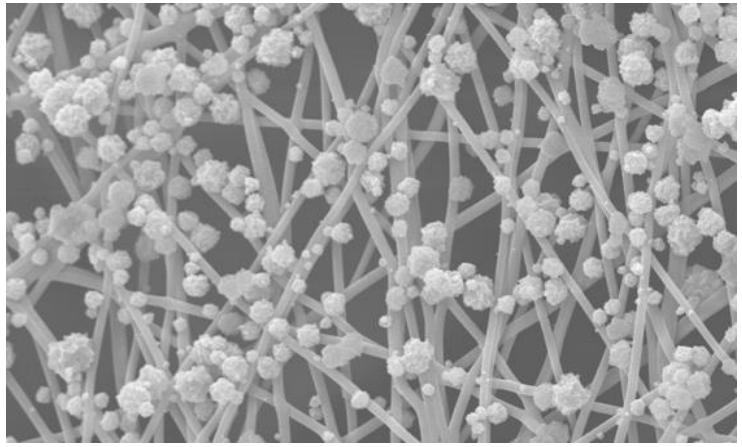
with coating without coating

MAP-1 for Medical Mask









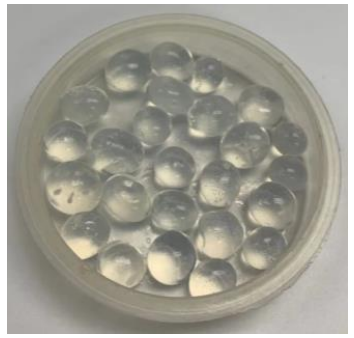
> 99 % reduction
bacteria and viruses

Fragrance release: Peppermint or lemon

> 98 % Filtration better than N95 but with better breathability

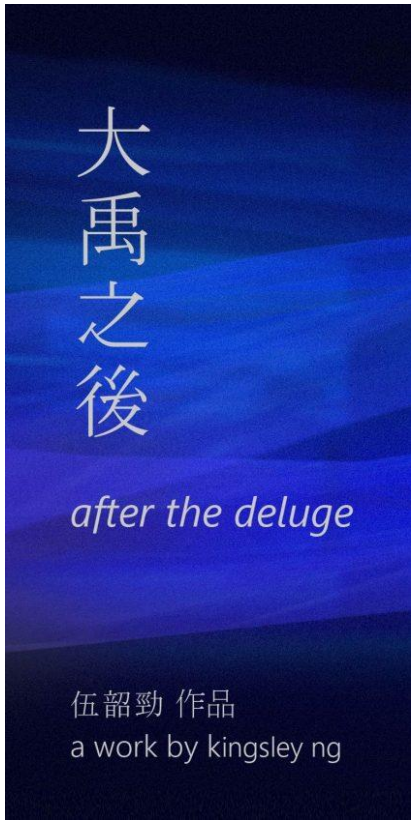
Water

MOChydroGel

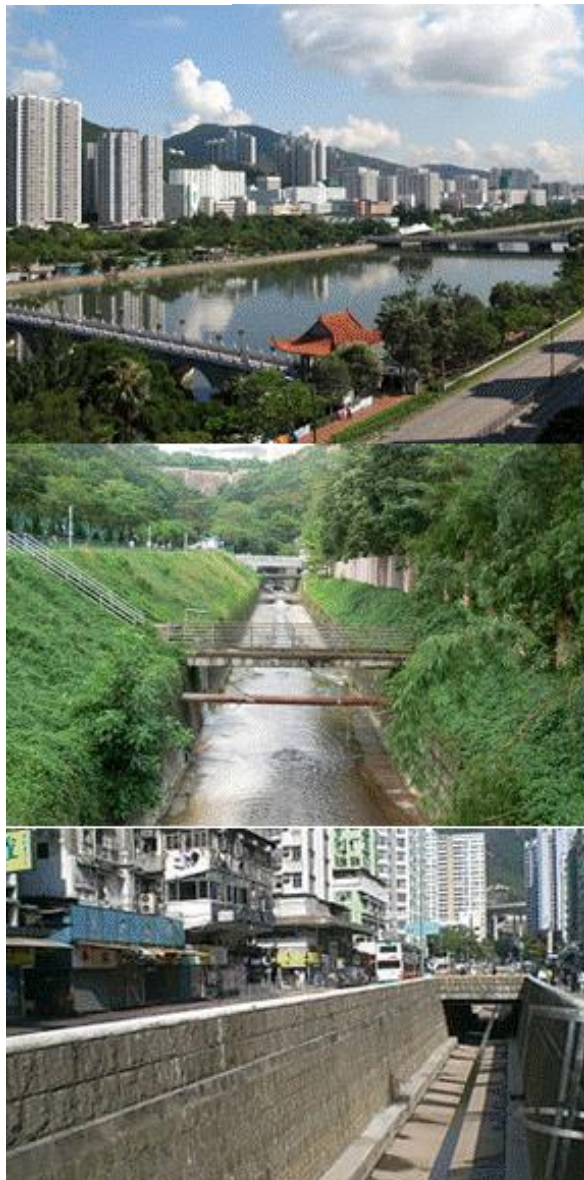


ITS/188/11
UIM/337

88-95 % H_2S Removal

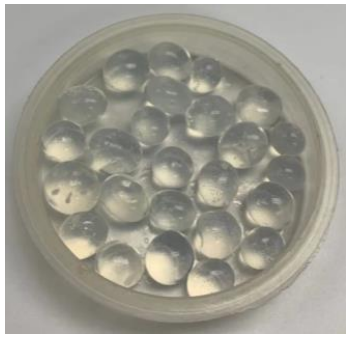


500 sites in HK
99 % decrease in Odor problem



MOChydroGel

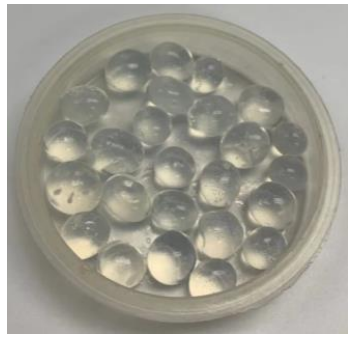
Microbial and Odor Control



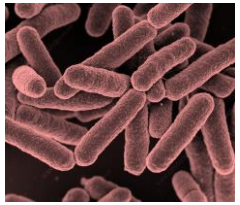
SST/024/20FP

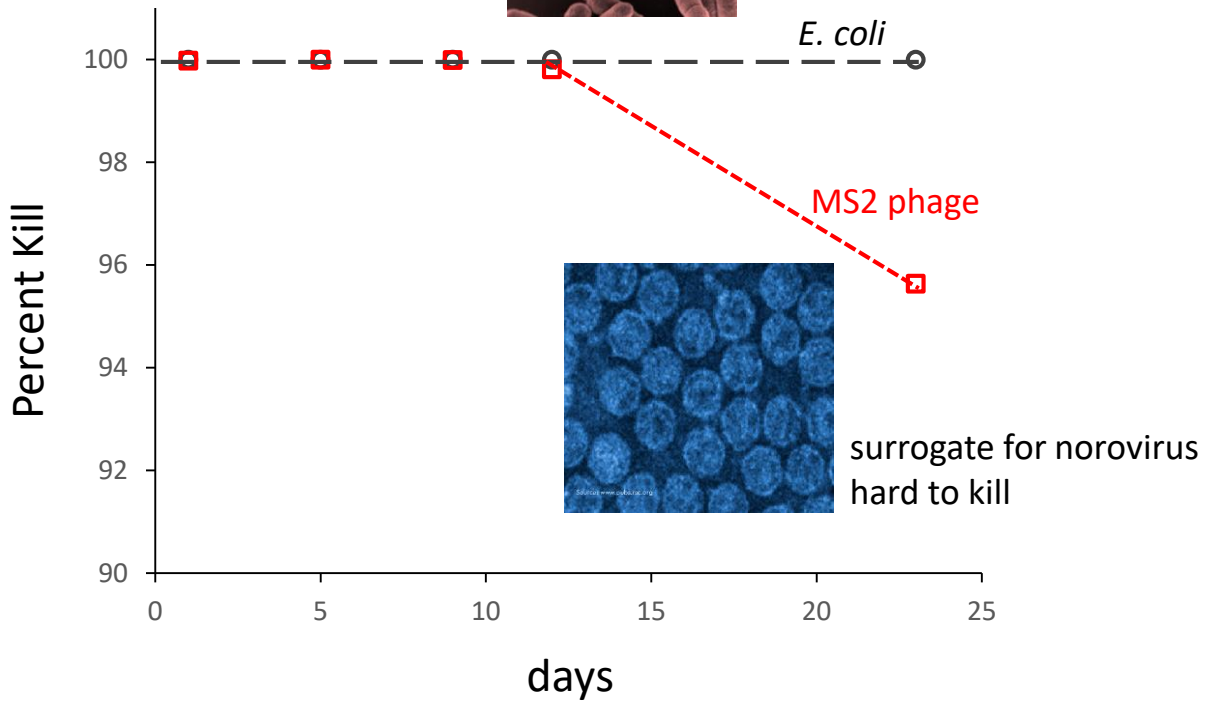
MOChydroGel

Microbial and Odor Control



SST/024/20FP

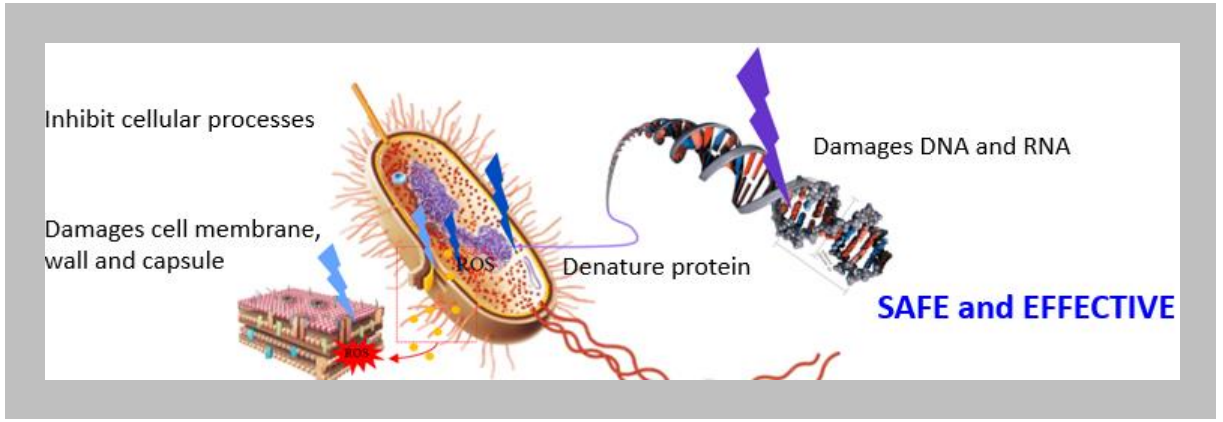


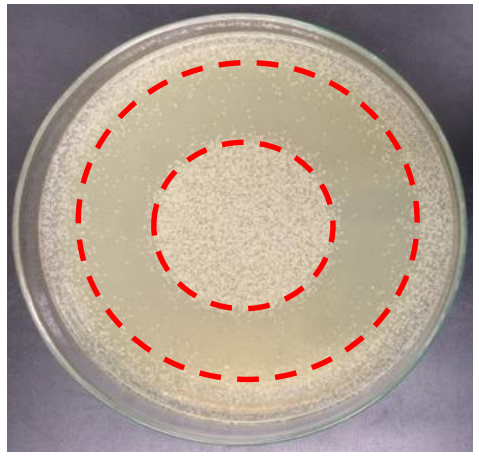


surrogate for norovirus
hard to kill

High Intensity Narrow Wavelength (Hi-NW)

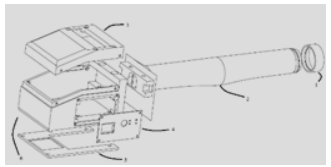
Javier López Navas





Efficient

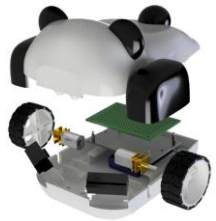
Handheld Devices



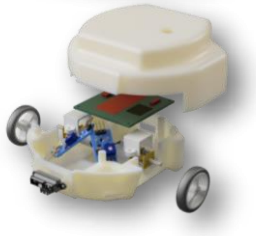
ITS/321/14

Autonomous Devices

Bed/Carpet



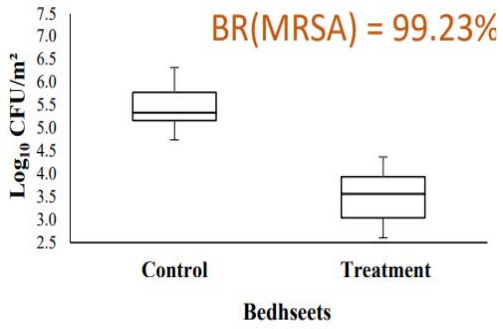
Table/Floor



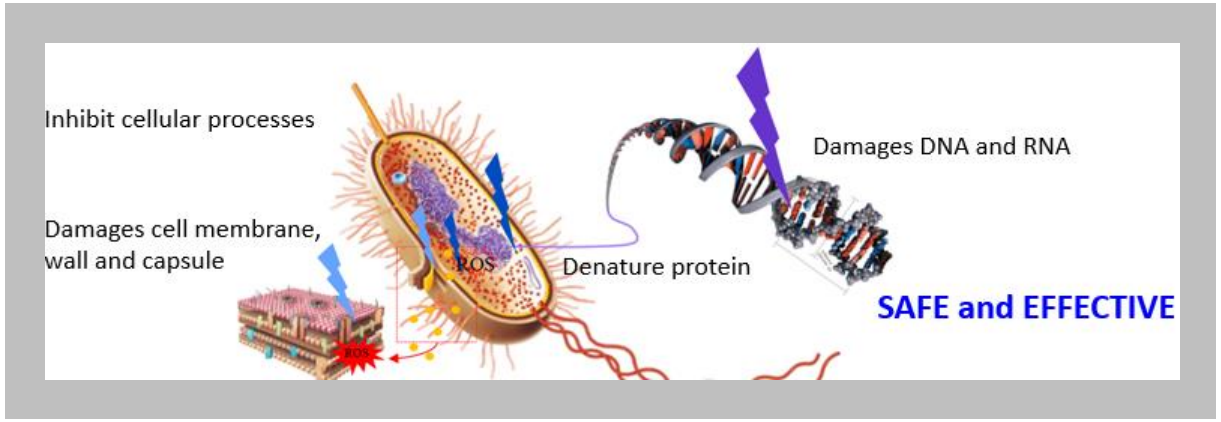
基督教 靈實協會 HAVEN OF HOPE CHRISTIAN SERVICE

Clinical Trial

Location: 3rd and 4th Floor of
Haven of Hope Woo Ping Care & Attention Home



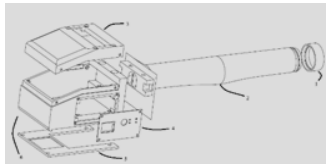
High Intensity Narrow Wavelength (Hi-NW)



利希慤基金
LEE HYSAN FOUNDATION

Javier López Navas

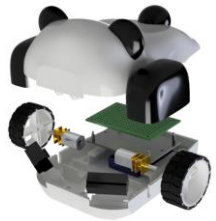
Handheld Devices



ITS/321/14

Autonomous Devices

Bed/Carpet

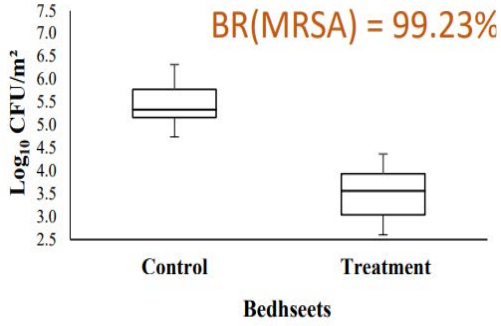


Table/Floor

基督教靈實協會 HAVEN OF HOPE CHRISTIAN SERVICE

Clinical Trial

Location: 3rd and 4th Floor of
Haven of Hope Woo Ping Care & Attention Home



Painless Microneedles

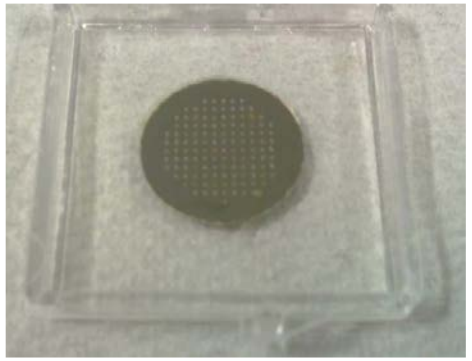
Painless

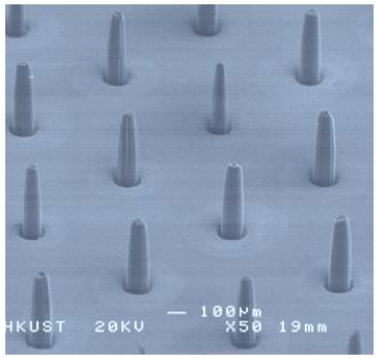
No Medical Waste

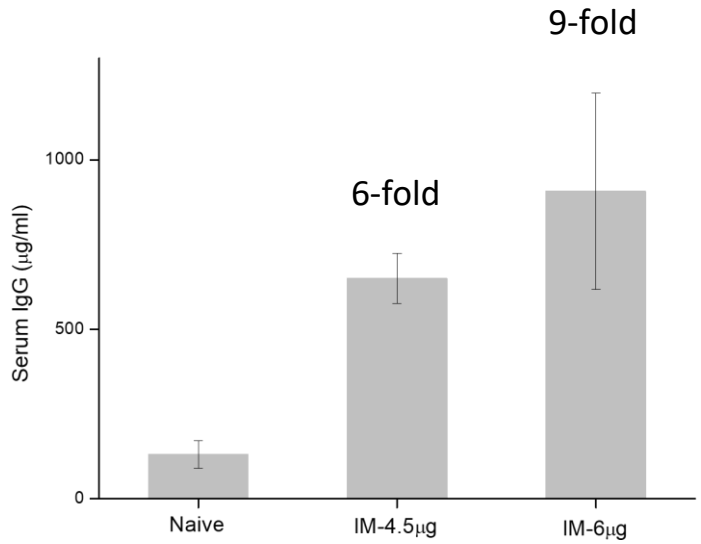
Easy to Use

Effective

Inexpensive







Acknowledgement

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We also thanks for contributions from:

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Mr. Winsor Lee Mr. Elio Zhao Mr. Manuel Arjonas Ms. Vincentia Ezeh Ms. Maria del Mar Calzado Delgado
Ms. Christy Suen Ms. Trixie Dy Ms. Qui Li Ms. Xin Miao Ms. Grace Zhang Ms. Diana Wu
Ms. Miriam Delgado Mr. Donald Lai

Thank You