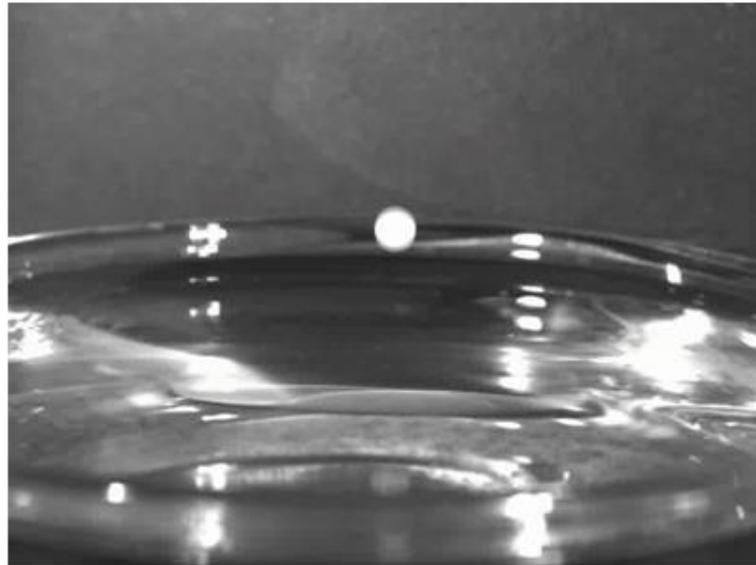


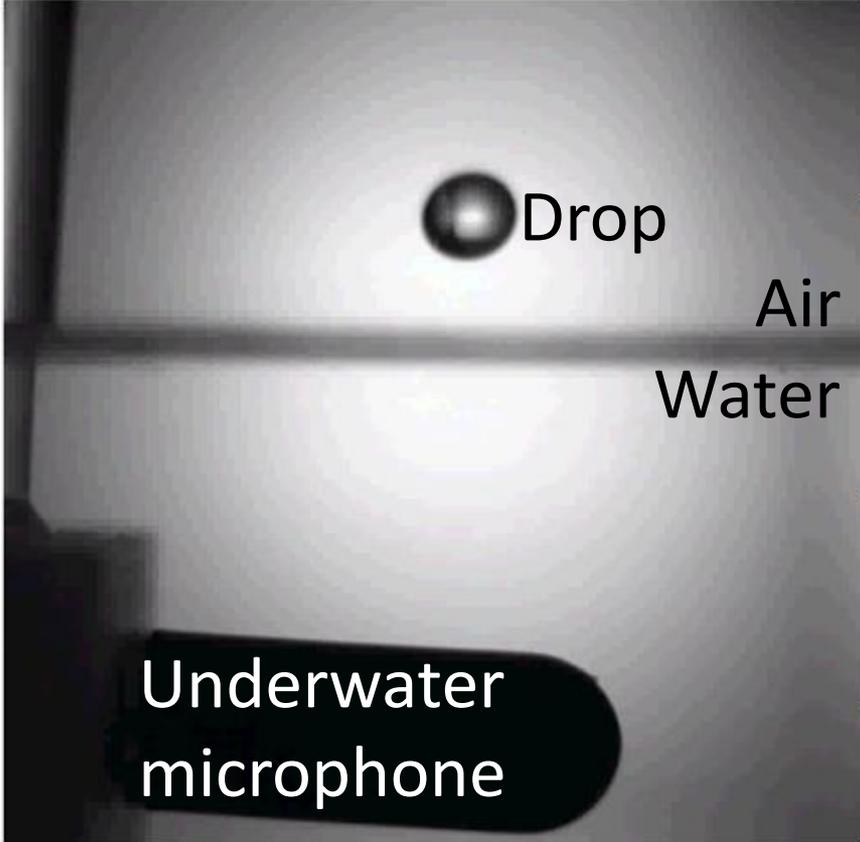
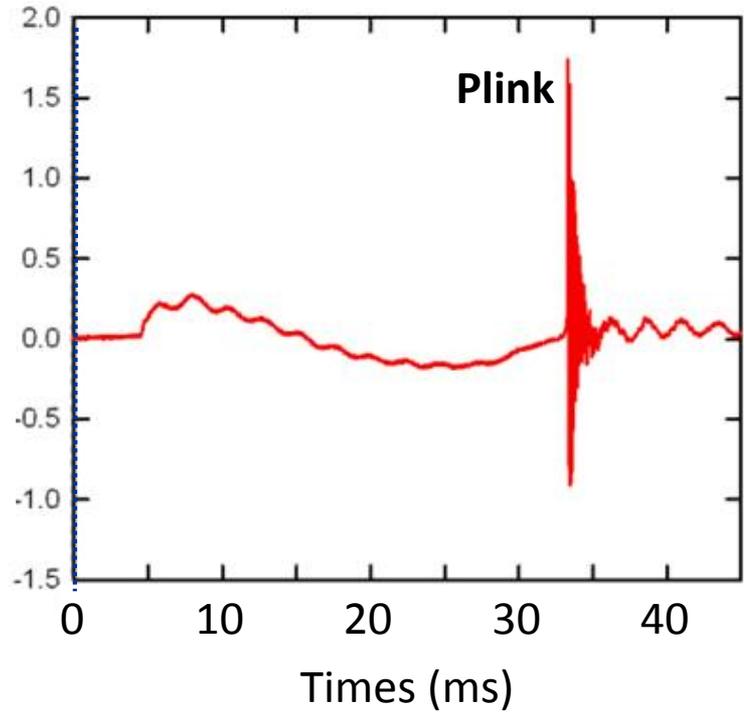
The use of bubble acoustics in cleaning and decontamination



Timothy Leighton FRS FREng FMedSci

Chair, Network for AntiMicrobial Resistance and Infection Prevention

Microphone signal (V)



Cleaning with cold water:

Cleaning baths

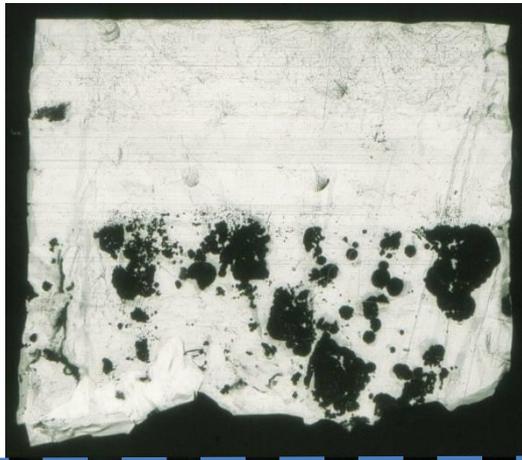
and

pressure washers:

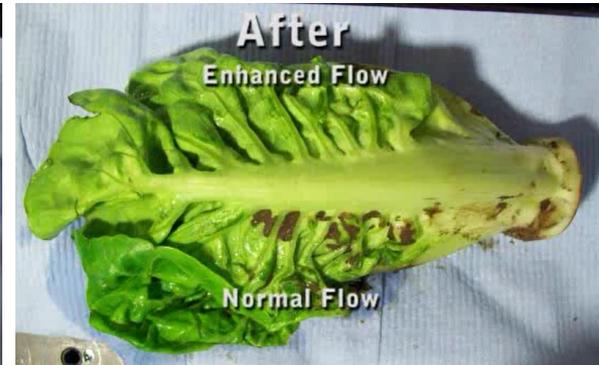
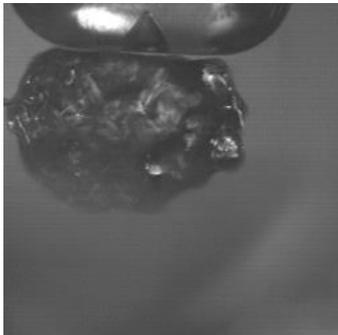


spray,
shred

Size,
soup



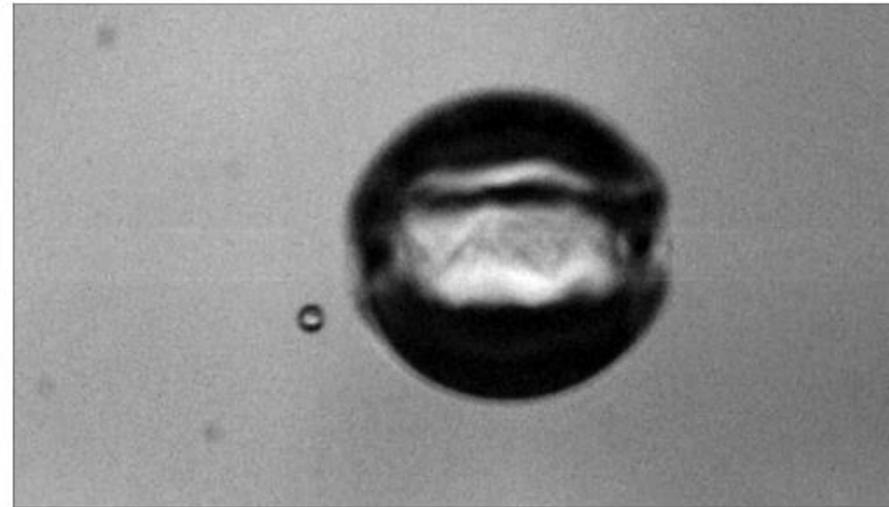
Cleaning
with dancing
bubbles:



After
Enhanced Flow

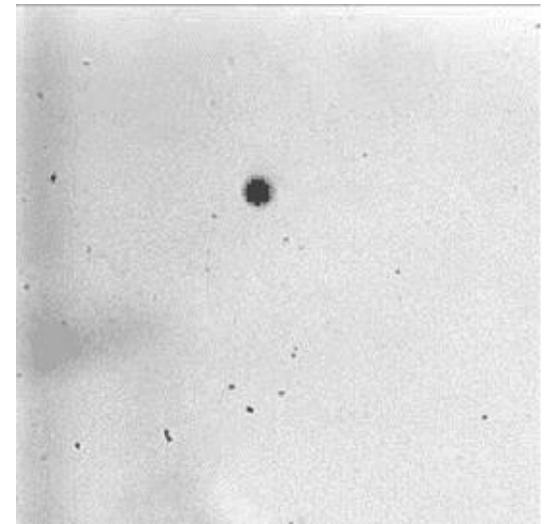
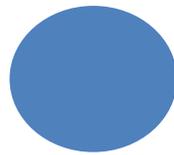
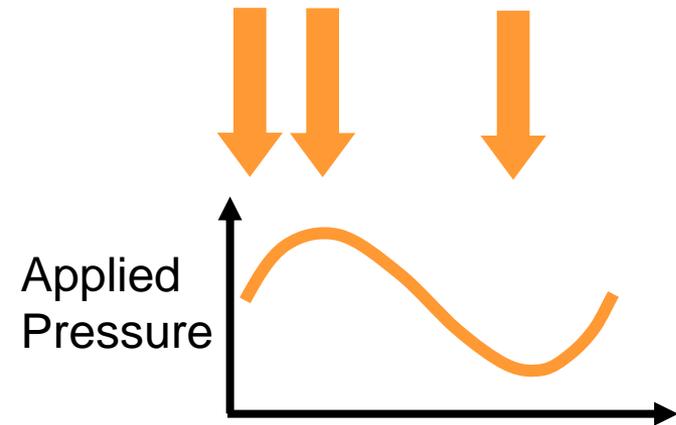
Normal Flow

Cold water cleaning:
No additives, no heating

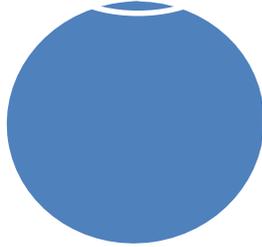


Cold water cleaning:

No additives, no heating



(courtesy Tom Maula)



$$\begin{aligned}
 \eta &= N + \frac{x_1(\sigma_1 - \omega_p/2) - y_1 Rd}{Q_i^0(x_1^2 + y_1^2)} U \\
 &\quad + \frac{y_1(\sigma_1 - \omega_p/2) + x_1 Rd}{Q_i^0(x_1^2 + y_1^2)} V, \\
 \mu &= N + \frac{x_1(\sigma_1 - \omega_p/2) + y_1 Rd}{Q_i^0(x_1^2 + y_1^2)} U \\
 &\quad + \frac{y_1(\sigma_1 - \omega_p/2) - x_1 Rd}{Q_i^0(x_1^2 + y_1^2)} V, \\
 \zeta &= (\sigma_1 - \omega_p/2)N + x_1 Q_i^0 U + y_1 Q_i^0 V, \\
 Rd &= \sqrt{Q_i^{0^2}(x_1^2 + y_1^2) - (\sigma_1 - \omega_p/2)^2}. \quad (18)
 \end{aligned}$$

Differentiating equations (18) by t and expressing derivations of N, U, V by use equation (13), we obtain

$$\begin{aligned}
 \frac{\partial \eta}{\partial t} &= \lambda_1 \eta - 2Q_i^0 (yU(\eta, \mu, \zeta) - xV(\eta, \mu, \zeta)) \\
 &\quad - 2Q_i^0 N(\eta, \mu, \zeta) \\
 &\quad \cdot \left(y \frac{x_1(\sigma_1 - \omega_p/2) - y_1 Rd}{Q_i^0(x_1^2 + y_1^2)} \right. \\
 &\quad \left. - x \frac{y_1(\sigma_1 - \omega_p/2) + x_1 Rd}{Q_i^0(x_1^2 + y_1^2)} \right) \quad (19a)
 \end{aligned}$$

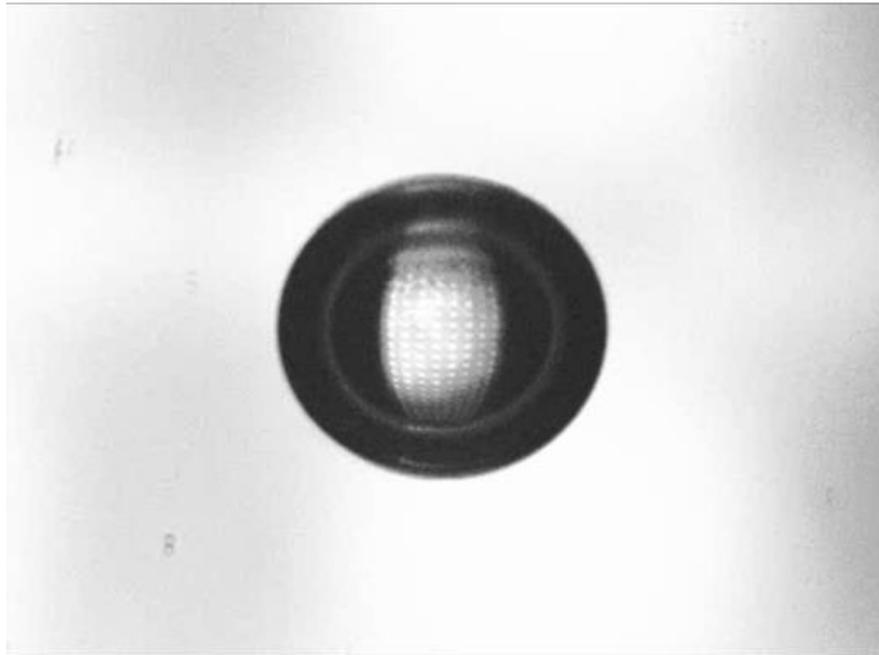
$$\begin{aligned}
 \frac{\partial \mu}{\partial t} &= \lambda_2 \mu - 2Q_i^0 (yU(\eta, \mu, \zeta) - xV(\eta, \mu, \zeta)) \\
 &\quad - 2Q_i^0 N(\eta, \mu, \zeta) \\
 &\quad \cdot \left(y \frac{x_1(\sigma_1 - \omega_p/2) + y_1 Rd}{Q_i^0(x_1^2 + y_1^2)} \right. \\
 &\quad \left. - x \frac{y_1(\sigma_1 - \omega_p/2) - x_1 Rd}{Q_i^0(x_1^2 + y_1^2)} \right) \quad (19b)
 \end{aligned}$$

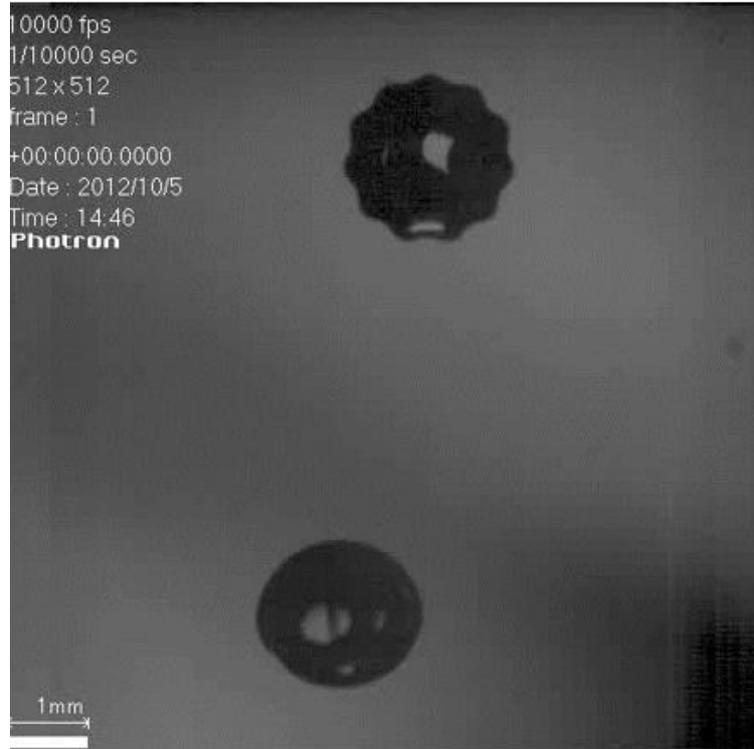
$$\begin{aligned}
 \frac{\partial \zeta}{\partial t} &= \lambda_3 \zeta - 2Q_i^0 (\sigma_1 - \omega_p/2) \\
 &\quad \cdot (yU(\eta, \mu, \zeta) - xV(\eta, \mu, \zeta)) \\
 &\quad - 2Q_i^0 N(\eta, \mu, \zeta) (x_1 y - y_1 x), \quad (19c)
 \end{aligned}$$

$$\begin{aligned}
 \frac{\partial x}{\partial t} &= -\gamma_0 (x - x_1) - (\omega_* - \omega_p)(y - y_1) \\
 &\quad - Q_0^t V(\eta, \mu, \zeta), \quad (19d)
 \end{aligned}$$

$$\begin{aligned}
 \frac{\partial y}{\partial t} &= -(\omega_* - \omega_p)(x - x_1) - \gamma_0 (y - y_1) \\
 &\quad - Q_0^t U(\eta, \mu, \zeta). \quad (19e)
 \end{aligned}$$

Maksimov, A. O. & Leighton, T. G. (2018) Acoustic radiation force on a parametrically distorted bubble, *J. Acoust. Soc. Am.*, **143**, 296-305





$$\begin{aligned}\eta &= N + \frac{x_1(\sigma_1 - \omega_p/2) - y_1 Rd}{Q_l^0(x_1^2 + y_1^2)} U \\ &\quad + \frac{y_1(\sigma_1 - \omega_p/2) + x_1 Rd}{Q_l^0(x_1^2 + y_1^2)} V, \\ \mu &= N + \frac{x_1(\sigma_1 - \omega_p/2) + y_1 Rd}{Q_l^0(x_1^2 + y_1^2)} U \\ &\quad + \frac{y_1(\sigma_1 - \omega_p/2) - x_1 Rd}{Q_l^0(x_1^2 + y_1^2)} V, \\ \zeta &= (\sigma_1 - \omega_p/2)N + x_1 Q_l^0 U + y_1 Q_l^0 V, \\ Rd &= \sqrt{Q_l^0{}^2(x_1^2 + y_1^2) - (\sigma_1 - \omega_p/2)^2}.\end{aligned}\quad (18)$$

Differentiating equations (18) by t and expressing derivations of N, U, V by use equation (13), we obtain

$$\begin{aligned}\frac{\partial \eta}{\partial t} &= \lambda_1 \eta - 2Q_l^0 (yU(\eta, \mu, \zeta) - xV(\eta, \mu, \zeta)) \\ &\quad - 2Q_l^0 N(\eta, \mu, \zeta) \\ &\quad \cdot \left(y \frac{x_1(\sigma_1 - \omega_p/2) - y_1 Rd}{Q_l^0(x_1^2 + y_1^2)} \right. \\ &\quad \left. - x \frac{y_1(\sigma_1 - \omega_p/2) + x_1 Rd}{Q_l^0(x_1^2 + y_1^2)} \right)\end{aligned}\quad (19a)$$

$$\begin{aligned}\frac{\partial \mu}{\partial t} &= \lambda_2 \mu - 2Q_l^0 (yU(\eta, \mu, \zeta) - xV(\eta, \mu, \zeta)) \\ &\quad - 2Q_l^0 N(\eta, \mu, \zeta) \\ &\quad \cdot \left(y \frac{x_1(\sigma_1 - \omega_p/2) + y_1 Rd}{Q_l^0(x_1^2 + y_1^2)} \right. \\ &\quad \left. - x \frac{y_1(\sigma_1 - \omega_p/2) - x_1 Rd}{Q_l^0(x_1^2 + y_1^2)} \right)\end{aligned}\quad (19b)$$

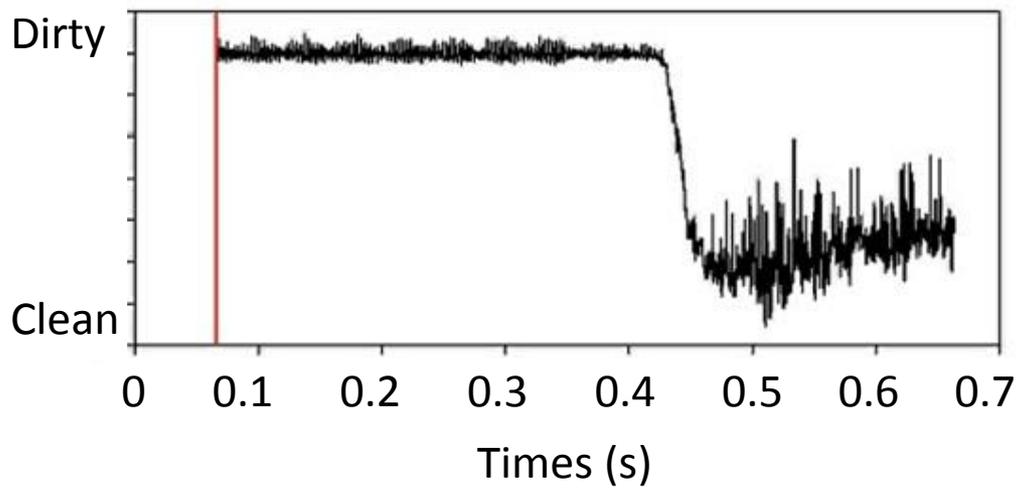
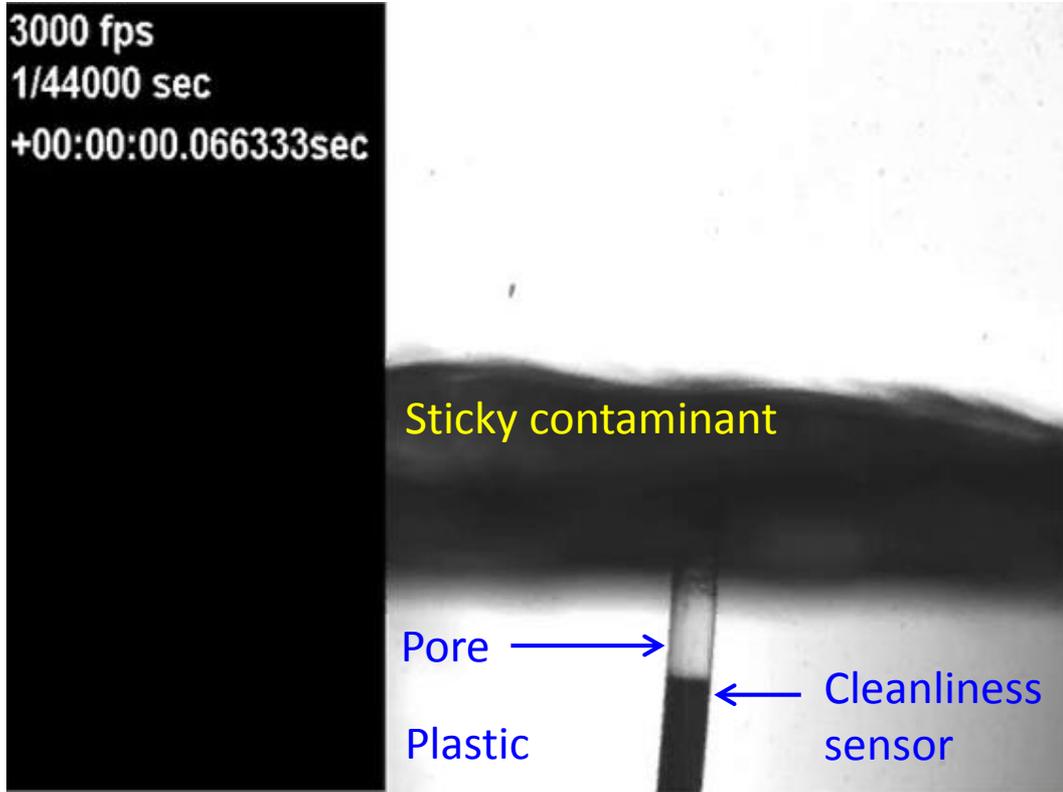
$$\begin{aligned}\frac{\partial \zeta}{\partial t} &= \lambda_3 \zeta - 2Q_l^0 (\sigma_1 - \omega_p/2) \\ &\quad \cdot (yU(\eta, \mu, \zeta) - xV(\eta, \mu, \zeta)) \\ &\quad - 2Q_l^0 N(\eta, \mu, \zeta) (x_1 y - y_1 x),\end{aligned}\quad (19c)$$

$$\begin{aligned}\frac{\partial x}{\partial t} &= -\gamma_0 (x - x_1) - (\omega_* - \omega_p)(y - y_1) \\ &\quad - Q_0^l V(\eta, \mu, \zeta),\end{aligned}\quad (19d)$$

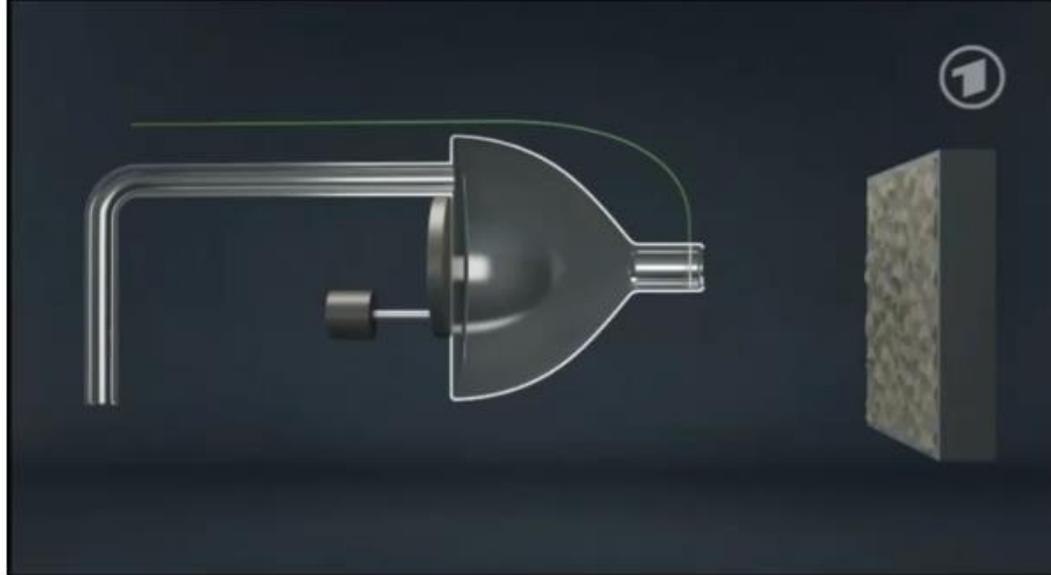
$$\begin{aligned}\frac{\partial y}{\partial t} &= -(\omega_* - \omega_p)(x - x_1) - \gamma_0 (y - y_1) \\ &\quad - Q_0^l U(\eta, \mu, \zeta).\end{aligned}\quad (19e)$$

Maksimov, A. O. & Leighton, T. G. (2018) Acoustic radiation force on a parametrically distorted bubble, *J. Acoust. Soc. Am.*, **143**, 296-305

Cold water cleaning:
No additives, no heating



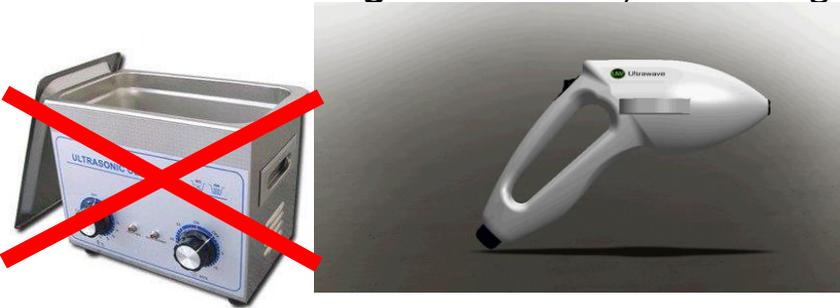
125 micron diameter pore



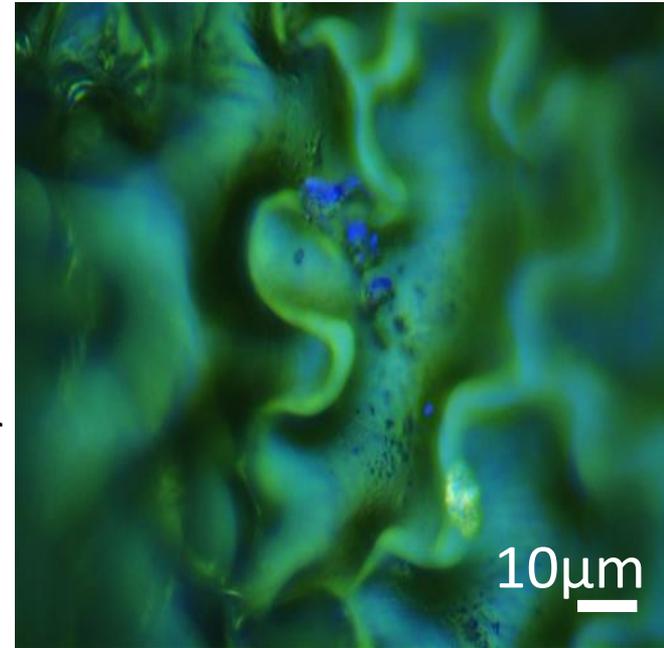
Soot on Porous Tile

StarStream

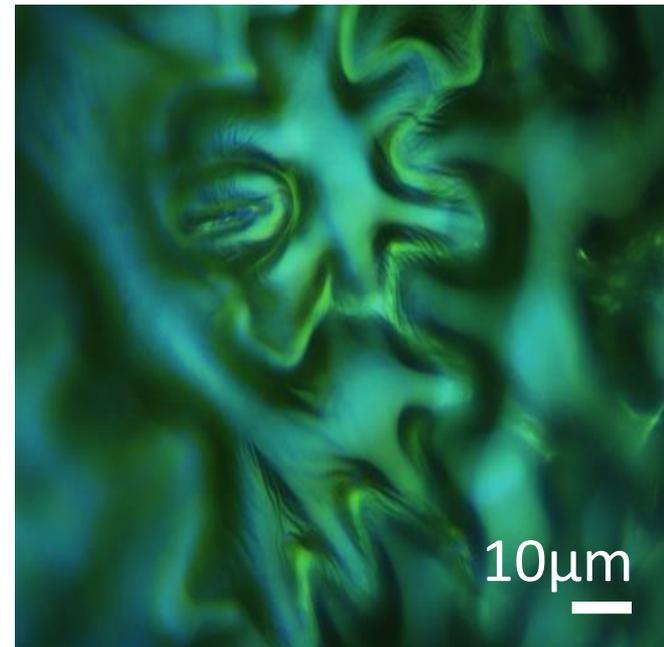
Cold water cleaning: No additives, no heating



Ready-to-eat Basil



1 minute
cold water



1 minute
StarStream



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Wires Home

Two die in E. coli outbreak linked to salad leaves

By PRESS ASSOCIATION

PUBLISHED: 14:04 EST, 18 July 2016 | UPDATED: 14:04 EST, 18 July 2016



Two people have now died after becoming infected with E. coli that may be linked to eating mixed salad leaves.

Public Health England (PHE) is investigating an outbreak of E. coli O157, which has so far affected 151 people, mainly in the South West.

There have been 144 cases in England, six in Wales and one in Scotland. PHE did not say when two people died.



Almost 100 ill as lettuce-linked E. coli outbreak hits 22 US states

US authorities are investigating whether romaine lettuce grown in Arizona, is the source of the outbreak of the bacteria.



Romaine lettuce is thought to be the potential source of an E. coli outbreak in the U.S.



By Sanya Burgess, News Reporter

Almost 100 people have fallen ill in the US after eating lettuce apparently contaminated with E. coli bacteria.

The US government is investigating whether romaine lettuce in Arizona could have been contaminated with the bacteria to the Centers for Disease Control and Prevention (CDC).

As of Friday, at least 98 people in 22 states have fallen sick, reports.

Forty-six of these have been treated in hospital.

Packaged salad listeria outbreak kills 1 in Macomb Co.



Ann Zaniewski, Detroit Free Press Education Writer

8:09 p.m. EST January 22, 2016



(Photo: Getty Images/iStockphoto)

One Michigan resident has died and three others fell ill as part of a listeria outbreak in six states linked to Dole packaged salads.

Officials are working to identify the source of the contamination and urging people to throw away salads that could be affected.

Twelve people in six states — Michigan, Indiana, Massachusetts, New Jersey, New York and

Pennsylvania — have been infected with the outbreak strain of *Listeria monocytogenes* since July 5, according to the Centers for Disease Control and Prevention.

The sole death was a person who lived in Macomb County. That person's name, age, gender and hometown have not been publicly released because of confidentiality rules, said Angela Miniucui, spokeswoman for the Michigan Department of Health and Human Services.

Although the outbreak began in July, officials were not able to isolate its source until January.

The outbreak was traced to a Dole processing facility in Springfield, Ohio. Dole has since shut down the facility and is withdrawing all packaged salads that were produced there, according to the CDC.

Officials are now hunting for the source.

"I liken this to a sort of food safety 'CSI.' It sometimes takes a while to identify a source of contamination, and sometimes a source is never identified," said Jennifer Holton, spokeswoman for the Michigan Department of Agriculture and Rural Development.

Basil Shelf life

+ 1 day

+ 2 day

+ 4 day

+ 7 day



Untreated control



Starstream spot clean



Starstream full clean

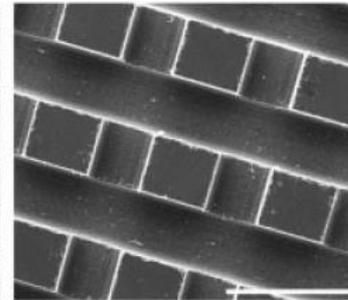
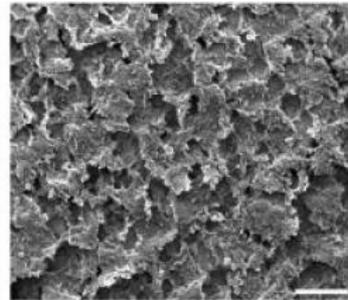
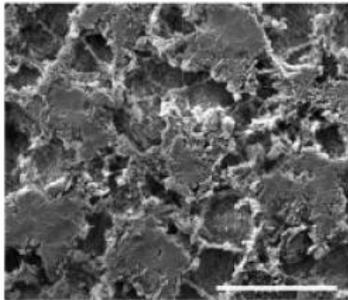
(Tom Secker and Bill Keevil)

Before...

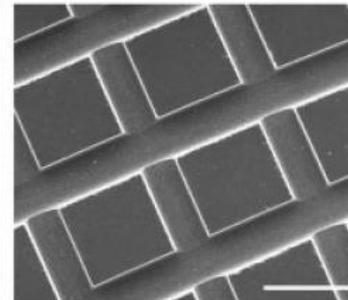
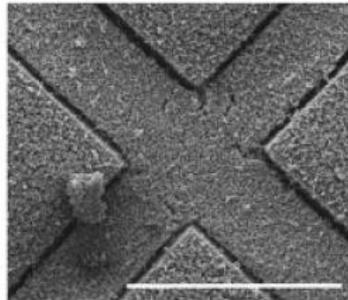
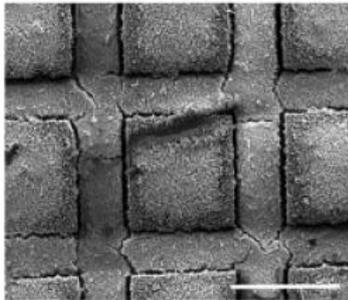
Water wash...

StarStream (cold water and no additives)

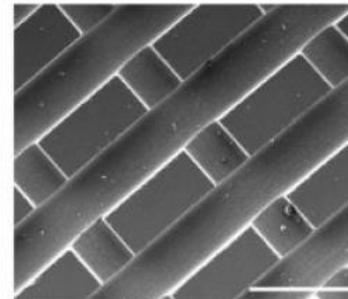
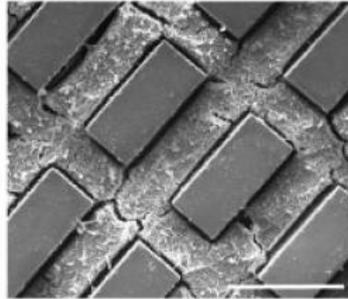
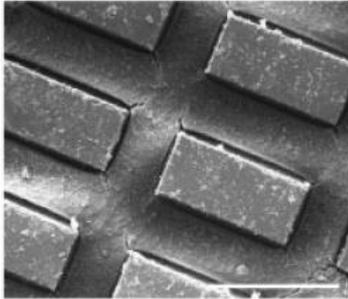
S. mutans



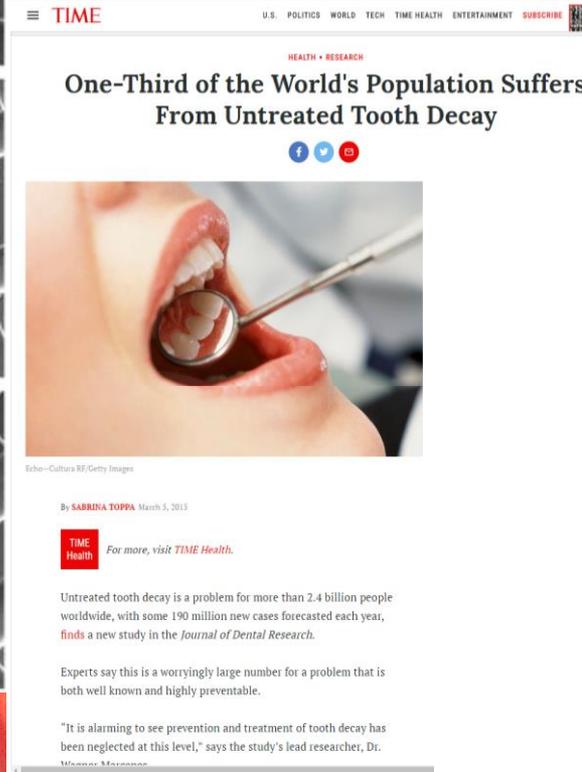
A. naeslundii



S. oralis

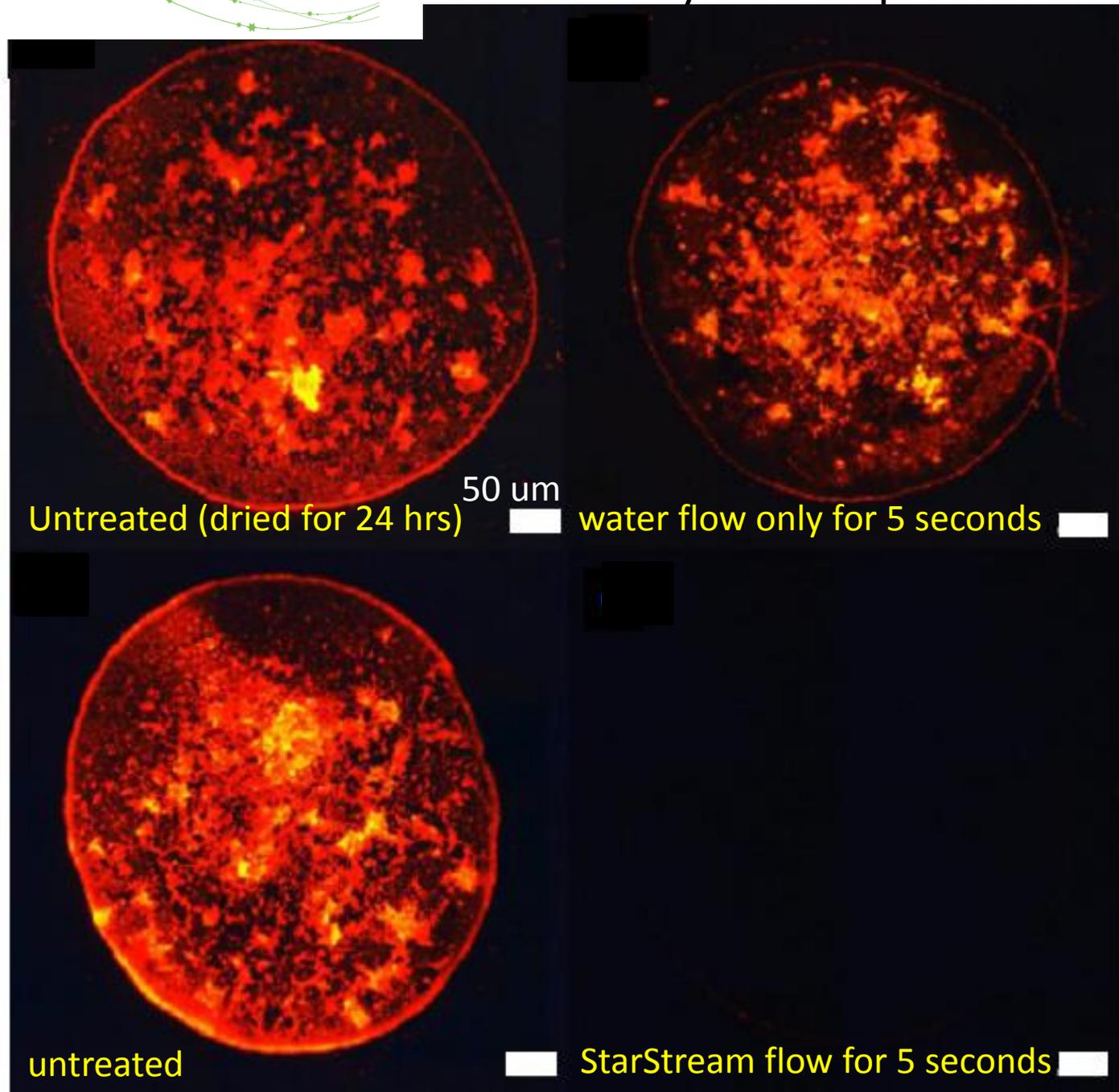


S. mutans



Scale bar=500 microns

Howlin R.P., Fabbri S., Offin D.G., Symonds N., Kiang K.S., Knee R.J., Yoganantham D.C., Webb J.S., Birkin P.R., Leighton T.G., Stoodley P. (2015) [Removal of dental biofilms with a novel ultrasonically-activated water stream](#). *Journal of Dental Research*, **94**(9), 1303-1309



Untreated (dried for 24 hrs) 50 um water flow only for 5 seconds

untreated StarStream flow for 5 seconds



EPSRC
@EPSRC

Follow

Researchers @unisouthampton to pilot deployment of the StarStream ultrasonic cleaning device in NHS hospitals
@NAMRIP_SotonUni ow.ly/euXs30i3xPQ



6:30 AM - 29 Jan 2018

8 Retweets 9 Likes



The Washington Post
Democracy Dies in Darkness

Health & Science

Olympus Faces New Trial Over Medical Scopes Tied To Superbug Deaths



(Kaiser Health News)

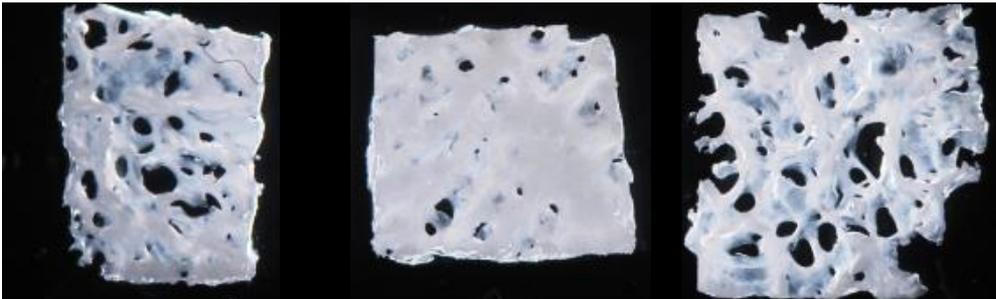
By Chad Terhune, Kaiser Health News January 18

A Seattle judge said Olympus Corp. failed to properly

Grafting bone between people for reconstructive surgery



No wash



1 week
 H_2O_2



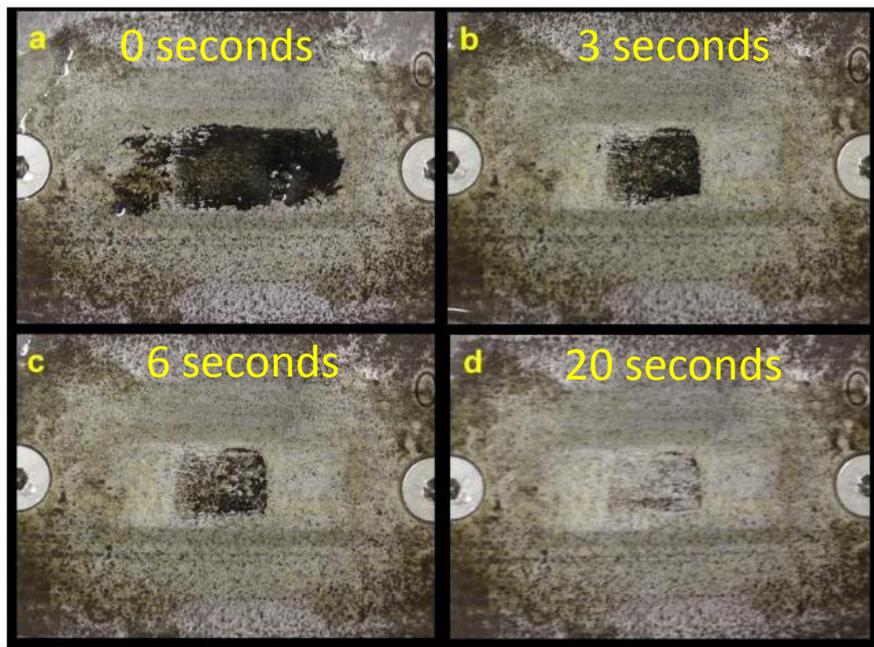
20 min
 H_2O_2



20 min
StarStream

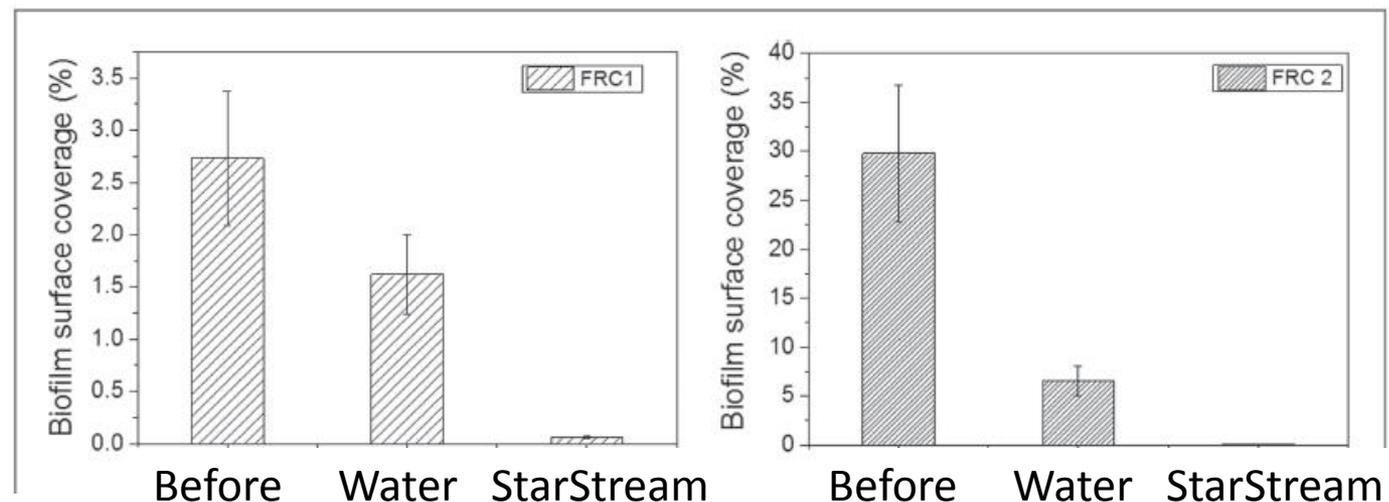


Birkin P.R., Offin D.G., Vian C.J.B., Howlin R.P., Dawson J.I., Secker T.J., Herve R.C., Stoodley P., Oreffo R.O.C., Keevil C.W. and Leighton T.G. (2015) [Cold water cleaning of brain proteins, biofilm and bone - harnessing an ultrasonically activated stream](#). *Physical Chemistry Chemical Physics*, **17**, 20574-20579

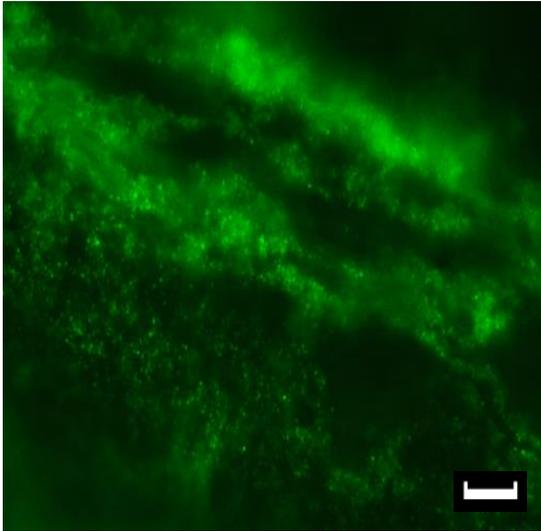


Goodes, L., Harvey, T., Symonds, N. and Leighton, T.G. (2016) [A comparison of ultrasonically activated water stream and ultrasonic bath immersion cleaning of railhead leaf-film contaminant](#). *Surface Topography: Metrology and Properties*, **4**(3), 034003 (doi: [10.1088/2051-672X/4/3/034003](#)).

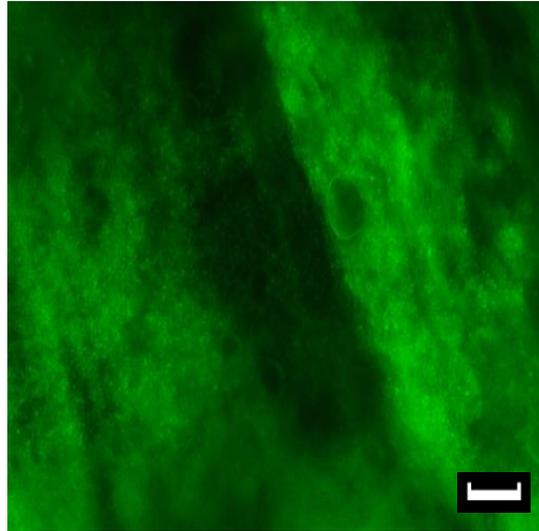
Salta, M., Goodes, L., Mass, B., Dennington, S., Secker, T. and Leighton, T.G. (2016) [Bubbles vs. biofilms: A novel method for the removal of marine biofilms attached on antifouling coatings using an ultrasonically activated water stream](#). *Surface Topography: Metrology and Properties*, **4**(3), 034009 (doi: [10.1088/2051-672X/4/3/034009](#)). The data for this paper are available at <http://eprints.soton.ac.uk/399420/>



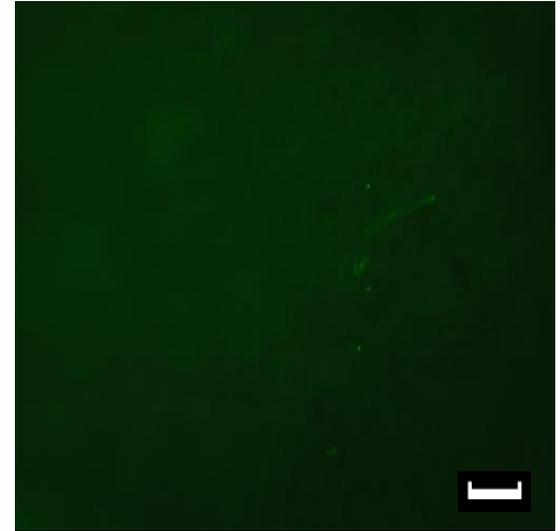
Preliminary – Planktonic *MRSA* removal



Untreated control



Saline control



Saline and UAS
(1 minute)

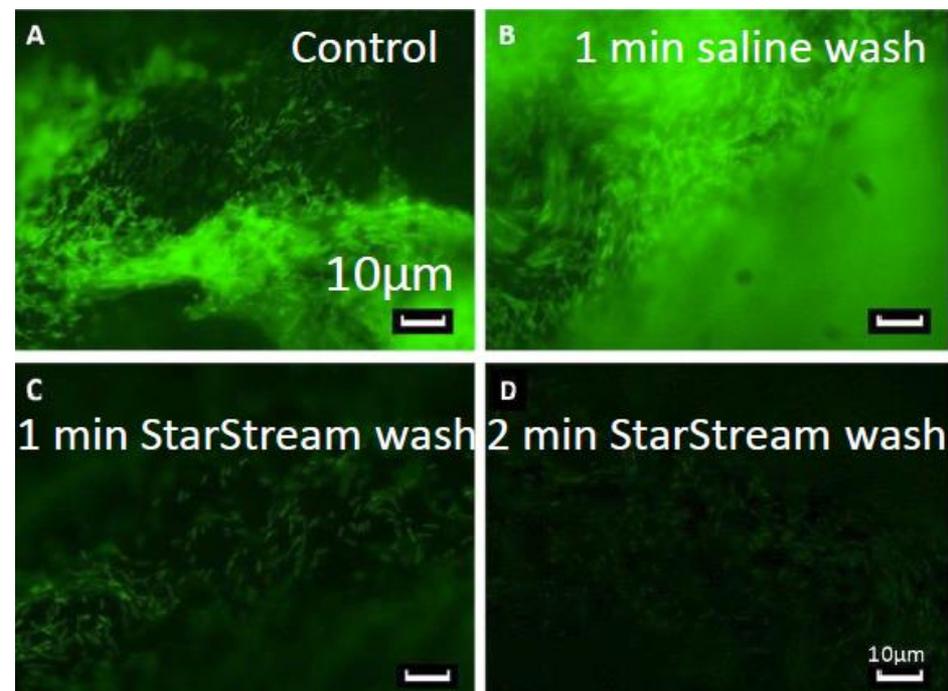


Planktonic MRSA was pre-stained so unlikely to adapt to the environment to form biofilm (waiting for red tagged rfp).

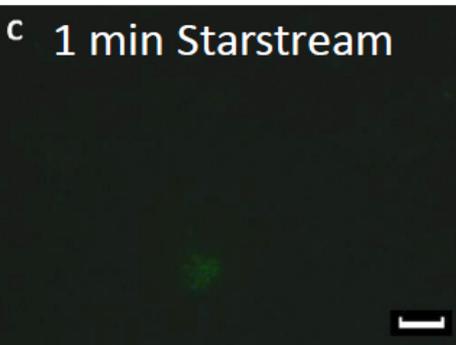
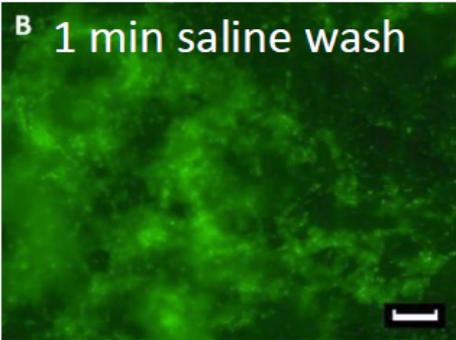
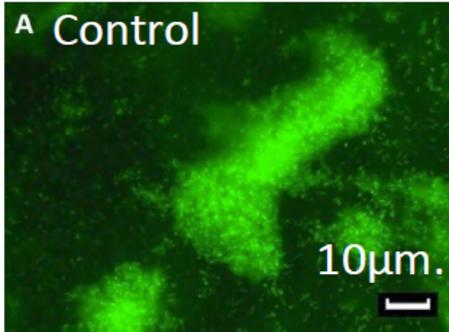
Pseudomonas aeruginosa, a multidrug resistant pathogen, common cause of hospital-acquired infections, transmitted by hands, generated a biofilm in a dead pig wound: ↓

↓
USA each year { 2 million patients annually infected
90,000 deaths annually
\$28 billion to 45 billion

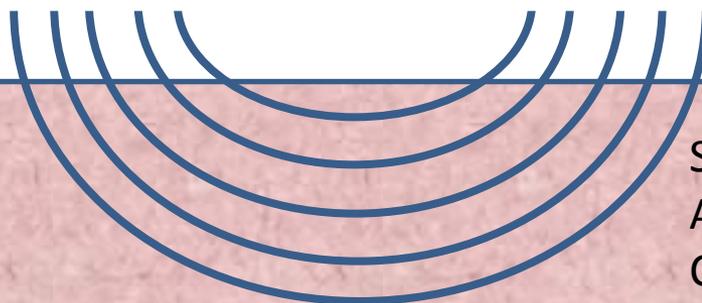
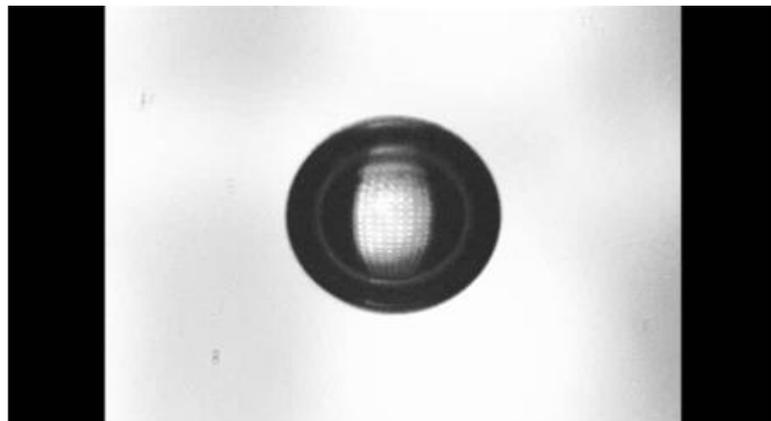
Pig trotter (dead)



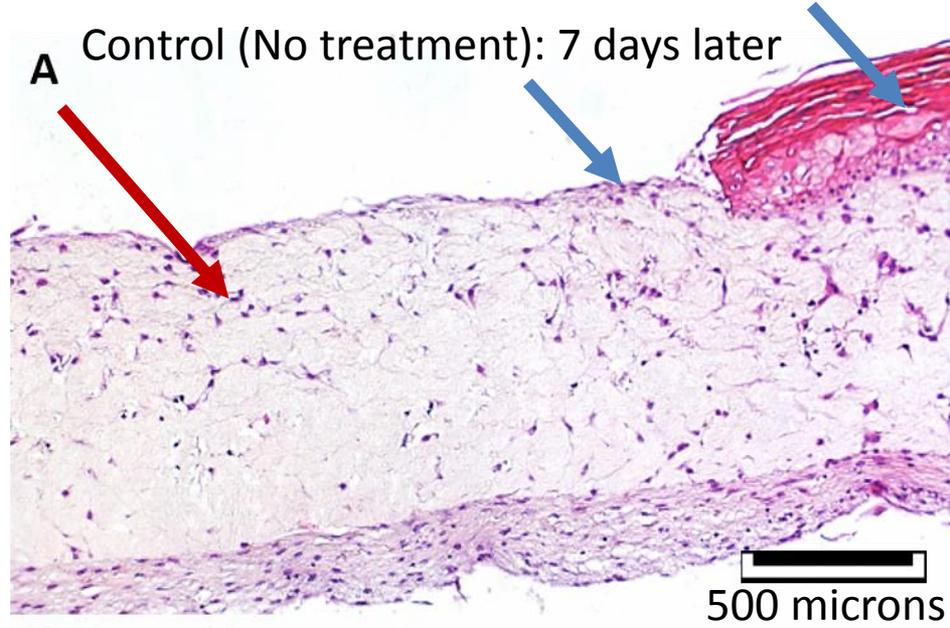
Biofilm removal – EpiDerm™ FT(alive)



StarHealer



Shear
Acoustic waves
Convection



StarHealer wash with cold water for 2 mins after injury, then wait 7 days

matrix metalloproteinase expression

StarHealer







ŞALLI AİLESİ HAYRATI

Bu kuyu CANSUYU-TÜRKİYE tarafından yapılmıştır

هذا البئر أسس من طرف جمعية CANSUYU تركيا

This water pump was made by CANSUYU-TURKIYE

Cela a été fait par CANSUYU-TURQUIE bien

GHANA 2015

1227







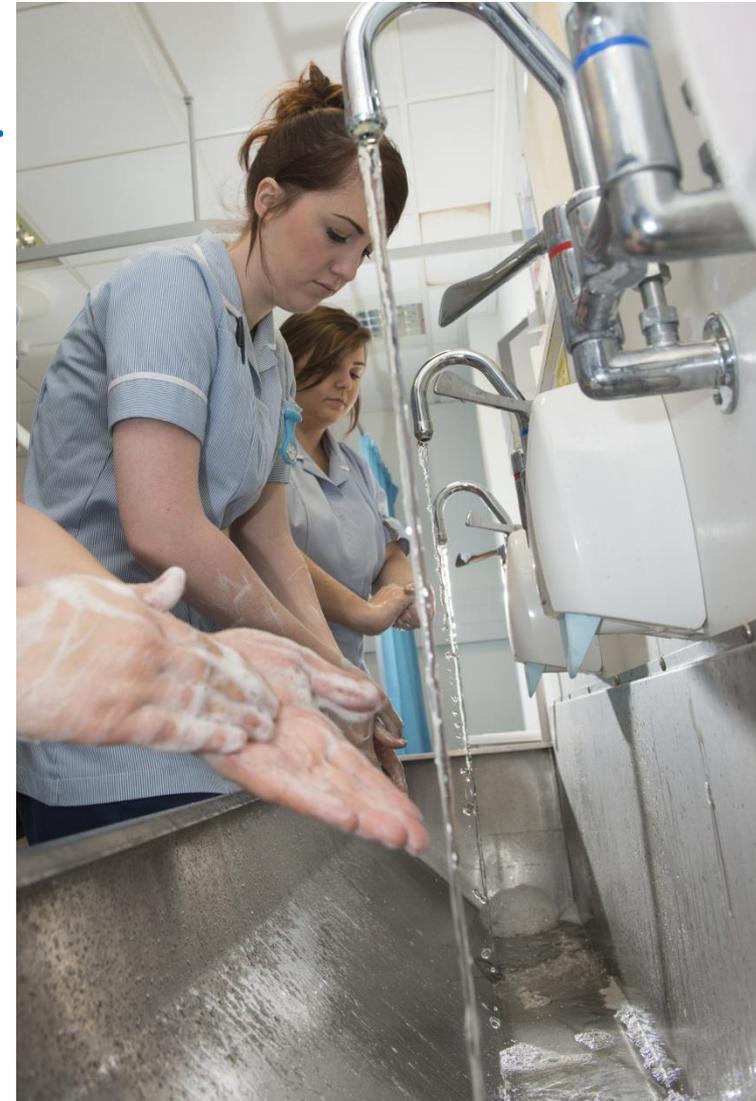
StarSaver



Firefighters use the hose from their engine to douse the young man in water

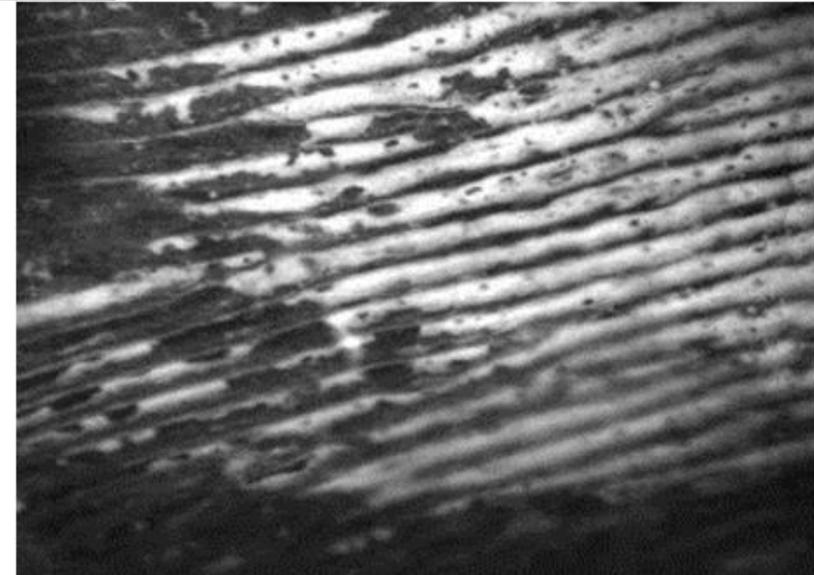
Reasons for not using anti-microbial agents: (a)...the skin has 'friendly' bacteria

The Centre for Disease Control recommends hands be washed for 20 s in warm soapy water.



In the UK the average wash is for 6s, often in cold water.

Reasons for not using anti-microbial agents: (a)...the skin has 'friendly' bacteria



Reasons for not using anti-microbial agents: (a)...the skin has 'friendly' bacteria (b)...Anti-Microbial Resistance

Unless a solution is found, by 2050, AntiMicrobial resistance (AMR) will cost the global economy more than the current size of the global economy, and be killing more people than cancer.

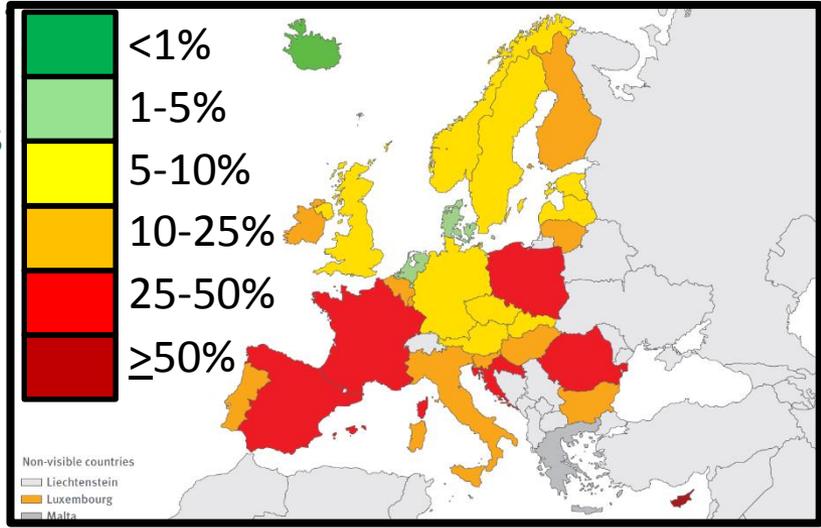
Optimism:

- researchers will find something (correctly identifying problem rather than selling solutions);
- drug companies will translate it cost-effectively to 7 billion people, in a manner that will allow ready take-up despite culture, infrastructure, training, behaviour, religion, migration, war, black market, and £100 million racehorses;
- 'someone' will keep discovering new drugs and successfully rolling them out to 7 billion people, faster than bugs become resistant to them

Pessimism: we must live in a world without antibiotics

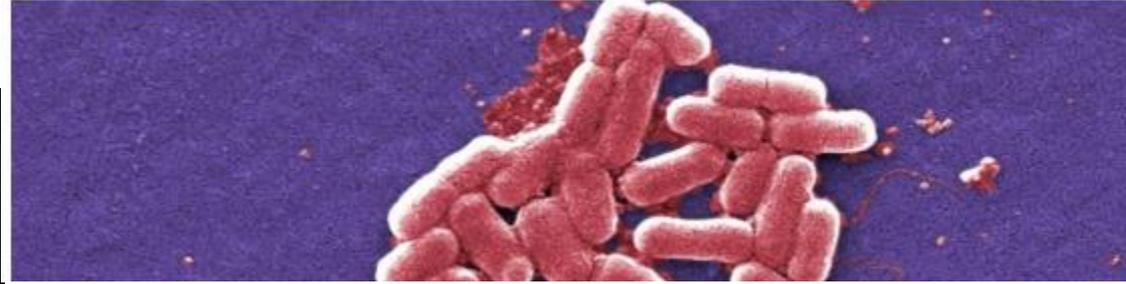
'The time may come when penicillin can be bought by anyone in the shops. Then there is the danger that the ignorant man may easily underdose himself and by exposing his microbes to non-lethal quantities of the drug make them resistant'

(Fleming, 1945 Nobel Prize acceptance speech)



% samples showing resistance to the macrolide* class on antibiotic as seen in samples of Streptococcus pneumoniae
*(erythromycin, spiramycin, telithromycin, azithromycin, clarithromycin)

New incentives needed to develop antibiotics to fight superbugs



Drugmakers are renewing efforts to develop medicines to fight emerging antibiotic-resistant bacteria, but creating new classes of drugs on the scale needed is unlikely to happen without new financial incentives to make the effort worth the investment, companies and industry experts said.



Shu Lam/The Malay Mail Online

The science world is freaking out over this 25-year-old's answer to antibiotic resistance

Could this be the end of superbugs?

FIONA MACDONALD 26 SEP 2016



A 25-year-old student has just come up with a way to fight drug-resistant superbugs *without* antibiotics.

The new approach has so far only been tested in the lab and on mice, but it could offer a potential solution to antibiotic resistance, which is now getting so bad that the United Nations recently declared it a "fundamental threat" to global health.



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News story

UK and China start global fund to tackle drug resistant infections

English

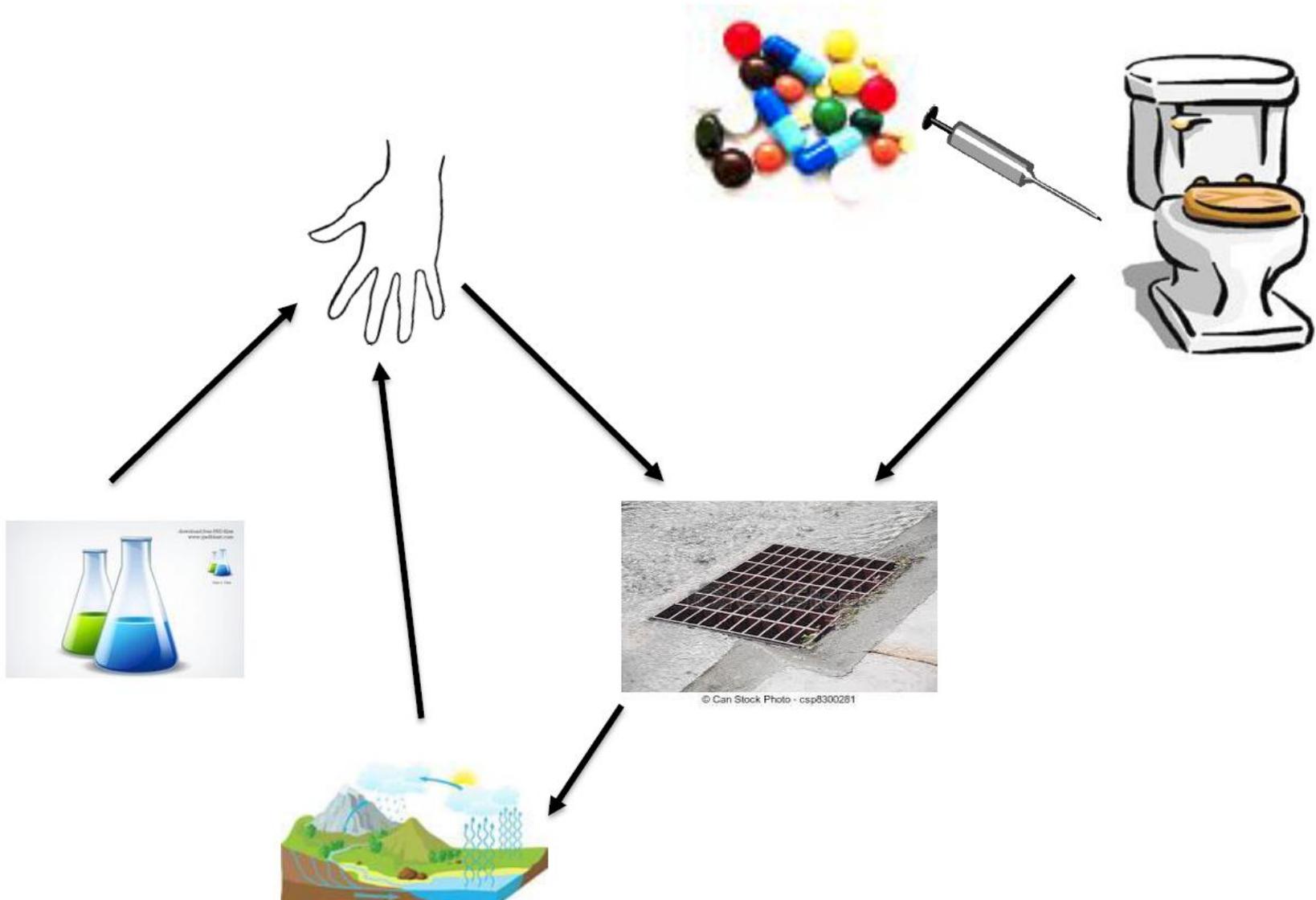
From: Department of Health and Prime Minister's Office, 10 Downing Street
First published: 23 October 2015
Part of: China

New fund to drive global response to antimicrobial resistance announced during Chinese President Xi Jinping's State Visit.



The UK and China will establish the Global Antimicrobial Research Innovation Fund and encourage further investment from governments and the private sector, helping to address the problems facing the world of medicine today.

Handwashing and wound cleaning





NM

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 THE ROYAL SOCIETY

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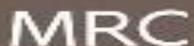
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 NERC
SCIENCE OF THE
ENVIRONMENT

 MRC

Medical
Research
Council

Confidence in Concept
Southampton

 Ultrawave
Precision ultrasonic cleaning equipment

Credits for the 'These are the hands' movie:

E. Roe, P. Hurley, J. Prieto, L. Schoonhoven, C. Veal, S. Wilks, X. Zhang, R. Zmijan, Mat Moyo, Wet Skills Lab. Shot by: J. Turp; Produced by P. Hurley. With thanks to EPSRC and M. Rosen for 'These are the hands'. Commissioned and funded by NAMRIP.