

# StarHealer

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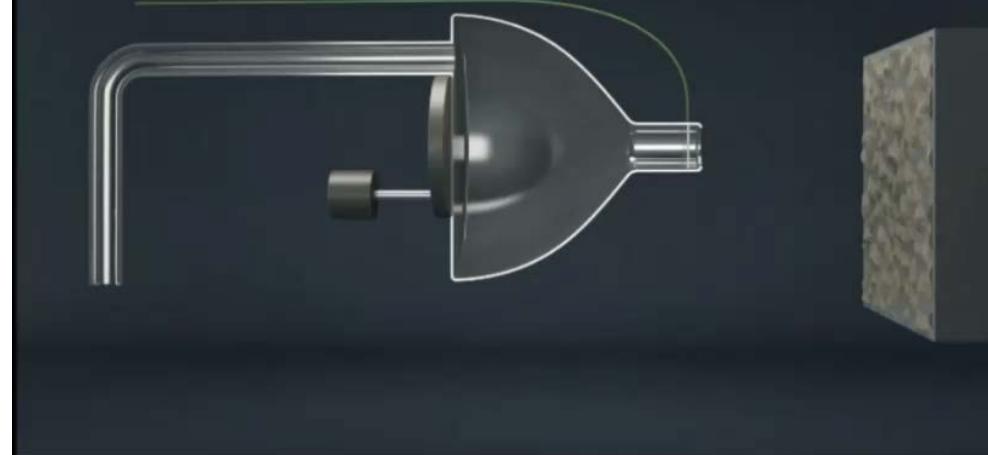
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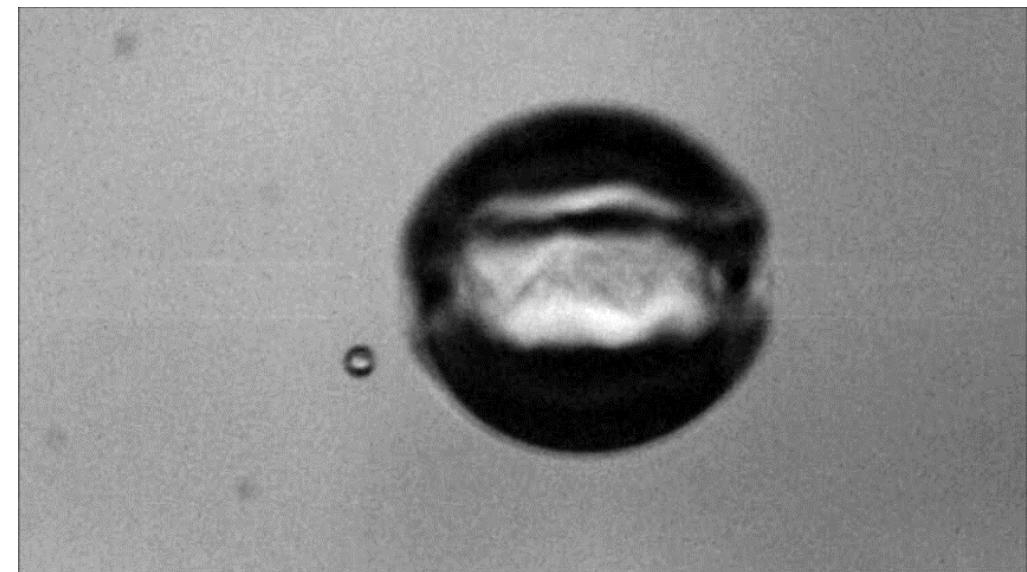
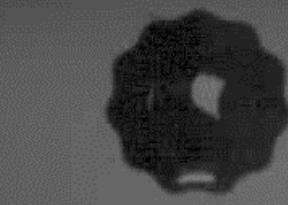
<sup>3</sup> Faculty of Engineering & the Environment, **University of Southampton**

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**StarStream**



10000 fps  
1/10000 sec  
512x512  
frame : 1  
+00:00:00.0000  
Date : 2012/10/5  
Time : 14:46  
**Photron**



Leighton, T.G. (2015) [The acoustic bubble: Oceanic bubble acoustics and ultrasonic cleaning](#). *Proceedings of Meetings on Acoustics (POMA)*, Acoustical Society of America, **24** (070006) <http://dx.doi.org/10.1121/2.0000121>



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

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

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

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

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

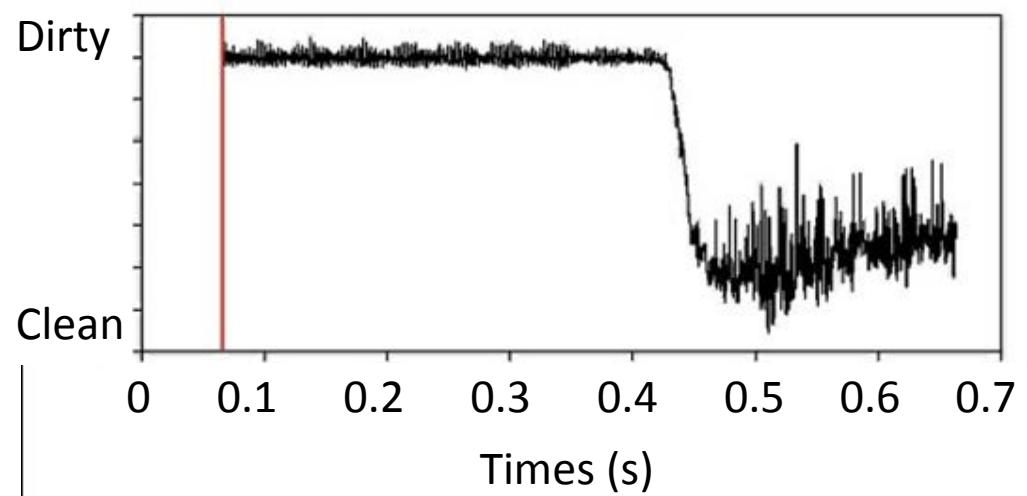
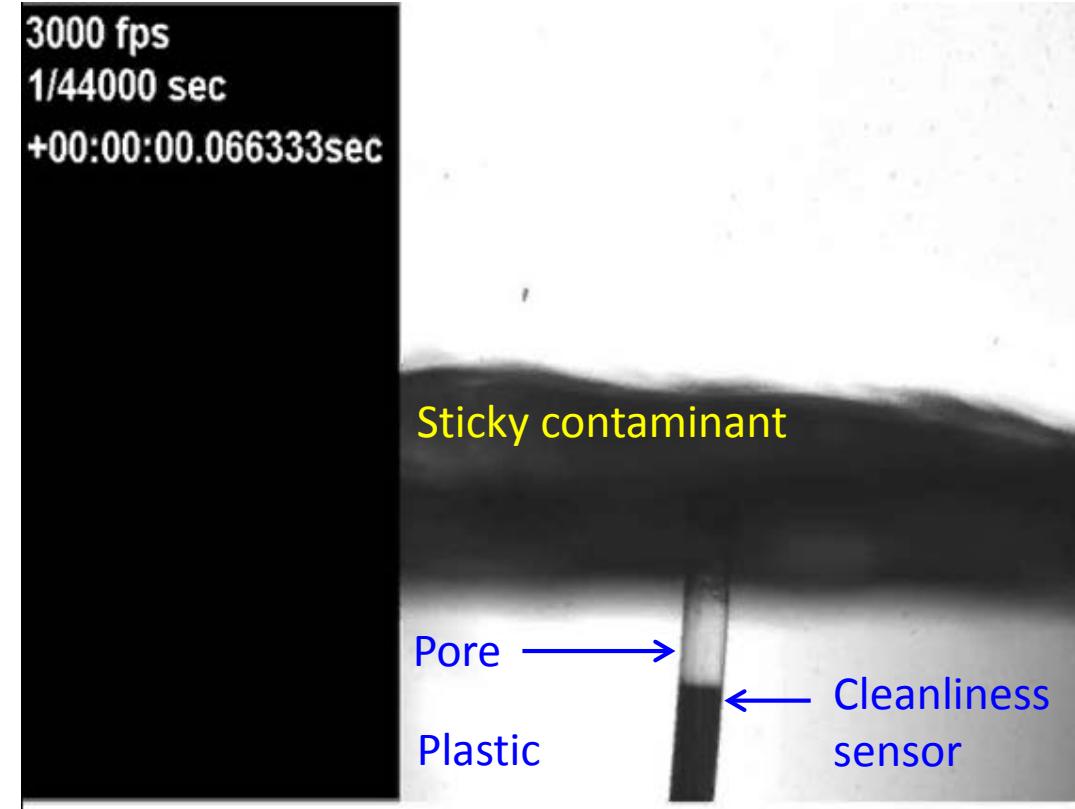
$$\begin{aligned}
\frac{\partial x}{\partial t} &= -\gamma_0(x - x_1) - (\omega_* - \omega_p)(y - y_1) \\
&\quad - Q_0^l V(\eta, \mu, \zeta), \quad (19d)
\end{aligned}$$

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

$$\begin{aligned}
&\cdot \frac{1}{R_0^2} \left[ (l_2 + 1)(l_2 + 2) \left\langle lm \middle| Y_{l_1 m_1} \middle| l_2 m_2 \right\rangle \right. \\
&\quad - \left\langle lm \middle| \frac{\partial Y_{l_1 m_1}}{\partial \theta} \frac{\partial}{\partial \theta} \middle| l_2 m_2 \right\rangle \\
&\quad \left. + m_1 m_2 \left\langle lm \middle| \frac{Y_{l_1 m_1}}{\sin^2 \theta} \middle| l_2 m_2 \right\rangle \right], \quad (7)
\end{aligned}$$

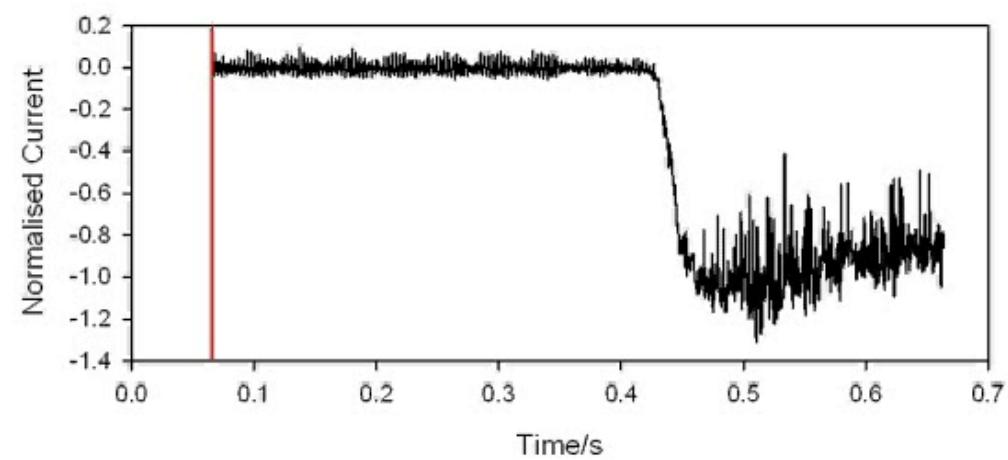
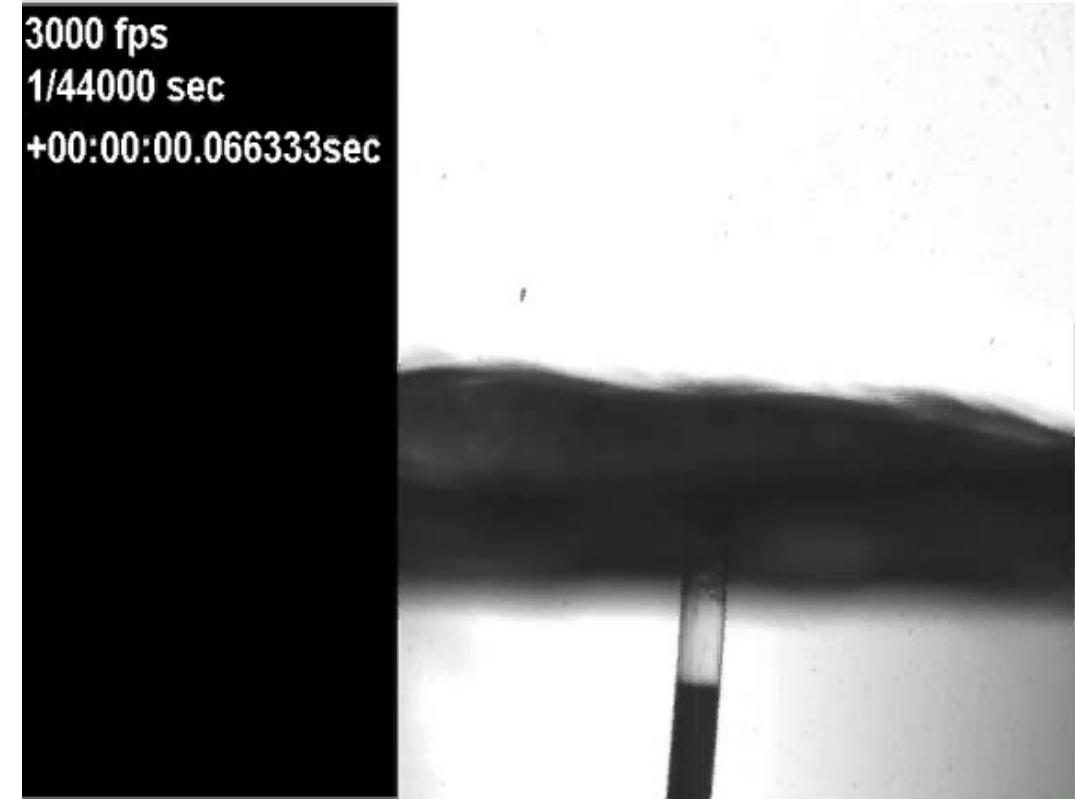
$$\begin{aligned}
\frac{\partial \phi_{lm}}{\partial t} &- \frac{\sigma}{\rho_0 R_0^2} (l - 1)(l + 2) \xi_{lm} - R_0 \omega_0^2 \bar{\xi} \sqrt{4\pi} \delta_{lm,00} \\
&= -\frac{P_m}{\rho_0} \sin(\omega_p t) \sqrt{4\pi} \delta_{lm,00} \\
&\quad + \left\{ \sum_{l_1 m_1} \sum_{l_2 m_2} \xi_{l_1 m_1} \dot{\phi}_{l_2 m_2} \delta_{m, m_1 + m_2} \right. \\
&\quad \cdot \frac{l_2 + 1}{R_0} \left\langle lm \middle| Y_{l_1 m_1} \middle| l_2 m_2 \right\rangle \\
&\quad - \sum_{l_1 m_1} \sum_{l_2 m_2} \phi_{l_1 m_1} \phi_{l_2 m_2} \delta_{m, m_1 + m_2} \\
&\quad \cdot \frac{1}{R_0^2} \left[ \frac{(l_2 + 1)(l_2 + 2)}{2} \left\langle lm \middle| Y_{l_1 m_1} \middle| l_2 m_2 \right\rangle \right. \\
&\quad \left. + \left\langle lm \middle| \frac{\partial Y_{l_1 m_1}}{\partial \theta} \frac{\partial}{\partial \theta} \middle| l_2 m_2 \right\rangle \right. \\
&\quad \left. - m_1 m_2 \left\langle lm \middle| \frac{Y_{l_1 m_1}}{\sin^2 \theta} \middle| l_2 m_2 \right\rangle \right] \\
&\quad - \frac{2\sigma}{\rho_0 R_0^2} \sum_{l_1 m_1} \sum_{l_2 m_2} \xi_{l_1 m_1} \xi_{l_2 m_2} \delta_{m, m_1 + m_2} \\
&\quad \cdot \left[ (l_2 + 1)l_2 - 1 \right] \left\langle lm \middle| Y_{l_1 m_1} \middle| l_2 m_2 \right\rangle \\
&\quad \left. + \omega_0^2 \left[ \bar{\xi}^2 - 3/2(\gamma + 1)\bar{\xi}^2 \right] \sqrt{4\pi} \delta_{lm,00} \right\}, \quad (8)
\end{aligned}$$

**Cold water cleaning:**  
No additives, no heating



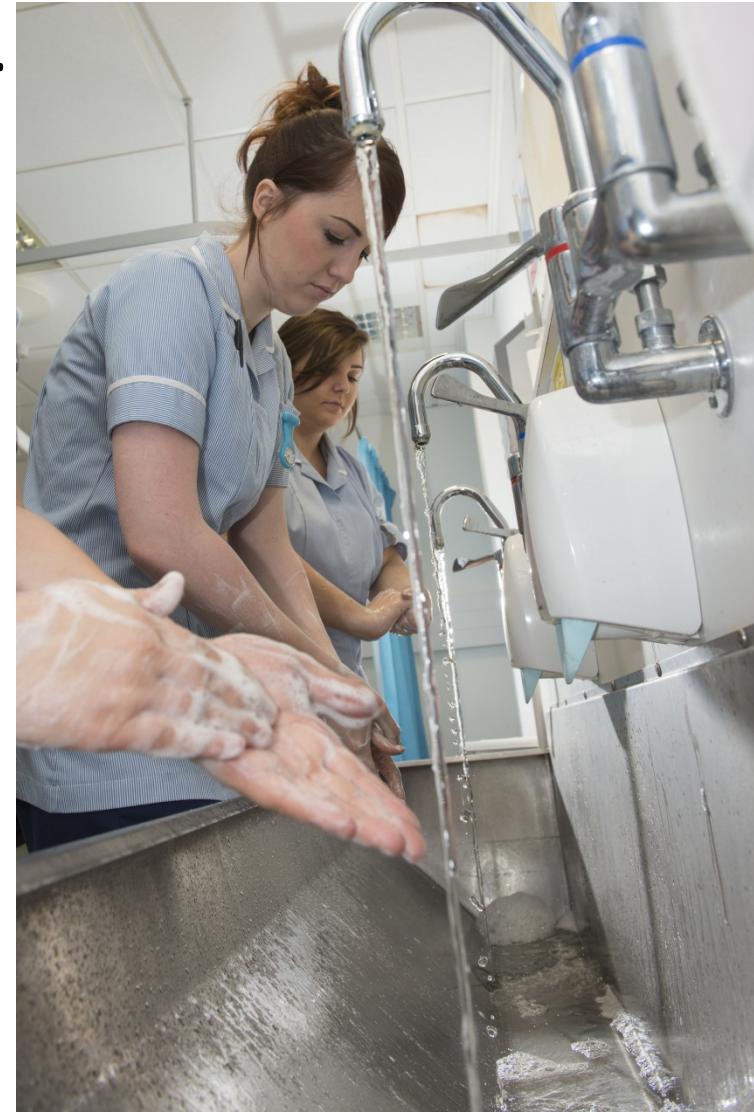
125 micron diameter pore

**Cold water cleaning:**  
No additives, no heating



**Soot on Porous Tile**

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.



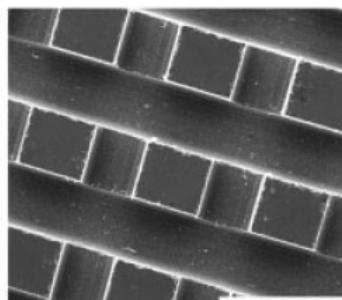
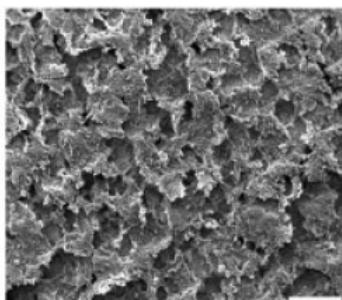
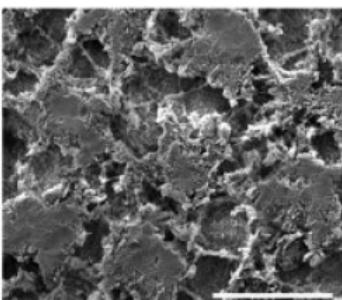
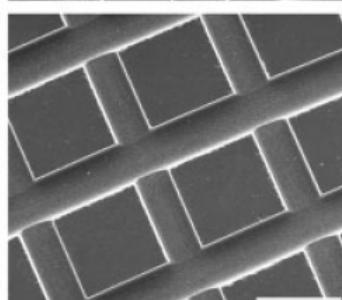
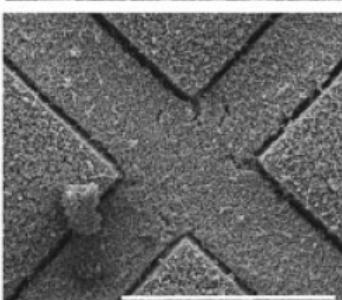
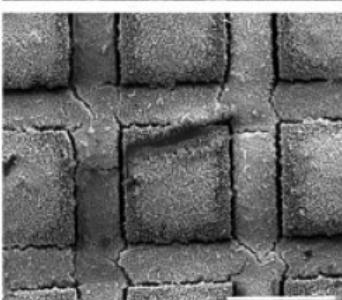
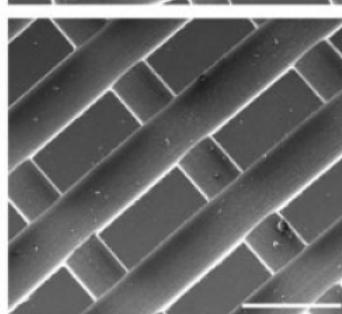
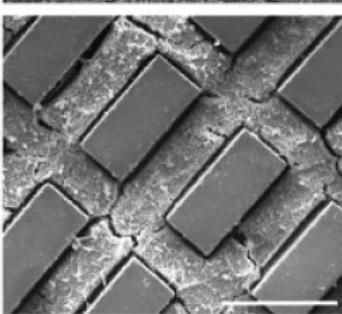
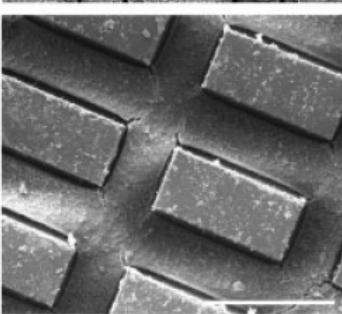
StarStream OFF (standard water, no additives)



Before...

Water wash...

StarStream (cold water and no additives)

***S. mutans******A. naeslundii******S. oralis******S. mutans***

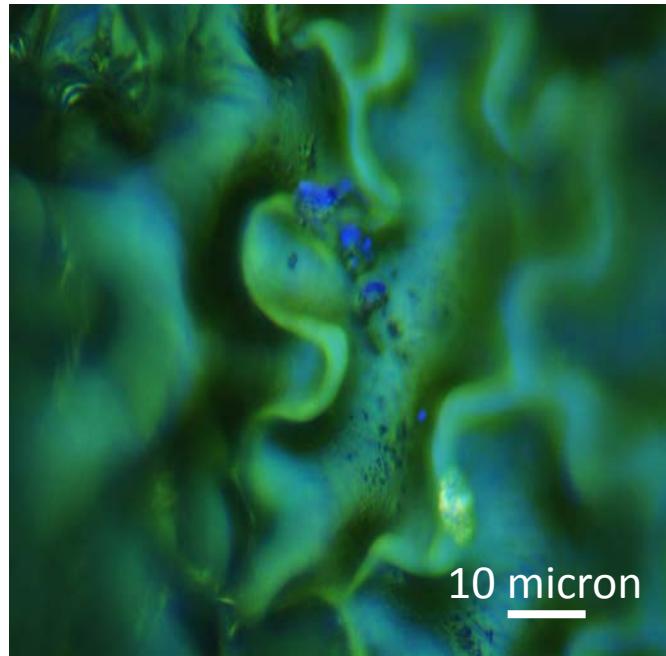
Scale bar=500 microns

(Rob Howlin and Paul Stoodley)

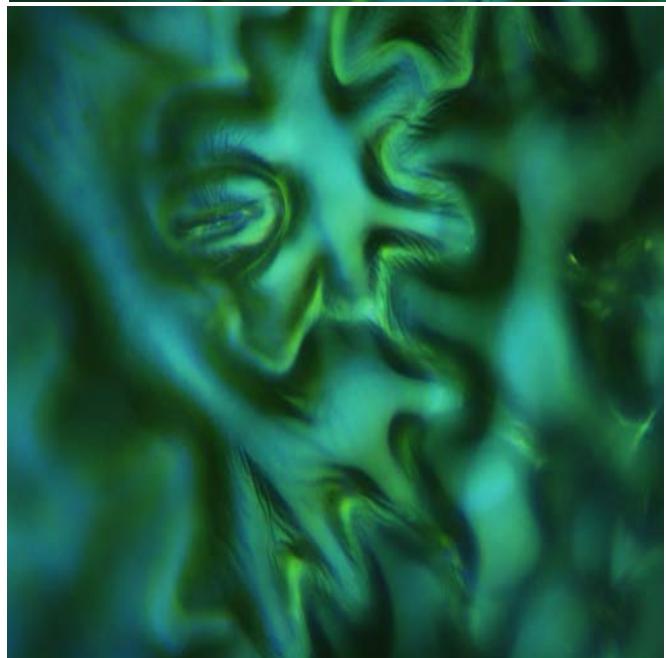
# Basil leaf



1 minute cold water



1 minute StarStream



## Basil Shelf life

+ 1 day



+ 2 day



+ 4 day



+ 7 day



Untreated control



Starstream spot clean



Starstream full clean

(Tom Secker and Bill Keevil)

## Packaged salad listeria outbreak kills 1 in Macomb Co.

By Ann Zaniewski, Detroit Free Press Education Writer 8:00 p.m. EST January 22, 2016



(Photo: Getty Images/Stockphoto)

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 Minicuci, 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.

### MORE STORIES



Prosecutor Kym Worthy to push no-parole sentences for 60

July 23, 2016, 7:14 a.m.



Former Allen Park mayor Levon King, wife die in small plane crash

July 23, 2016, 12:10 a.m.



Suspect held in 2014 Monroe County slaying of Chelsea Bruck

July 23, 2016, 12:04 a.m.

## Two die in E. coli outbreak linked to salad leaves

By PRESS ASSOCIATION

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



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13

shares

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 where the two people died.



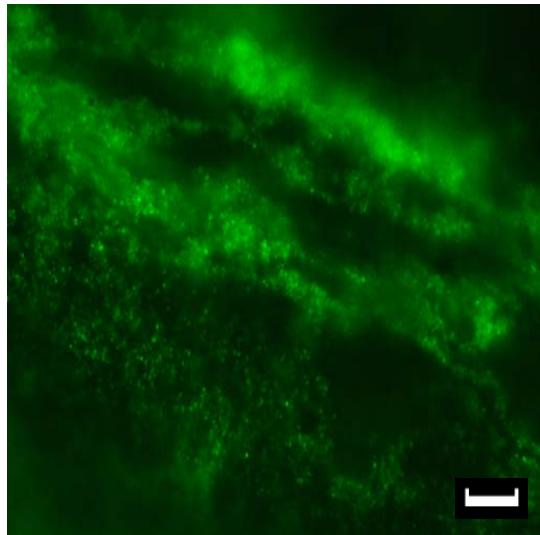
Experts are trying to trace the source of the E. coli outbreak

# Methods

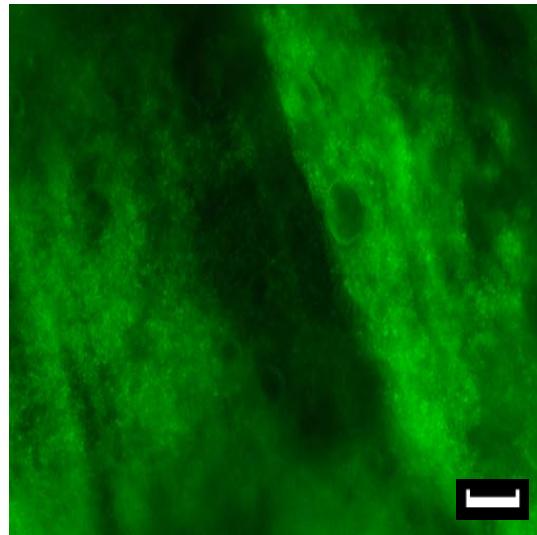


- Two *in vitro* wound models used, pig trotter (A) and (B) pre-wounded cultured human skin model (Epiderm™ FT, Mattek Inc, USA).
- Early stage biofilms cultured within wounds (E-MRSA-16, *P. aeruginosa* PAO1 pmf230).
- Wound models cleaned with either a saline wash or saline delivered via *StarStream*, and residual bacteria visualised by direct *in situ* epifluorescence microscopy.

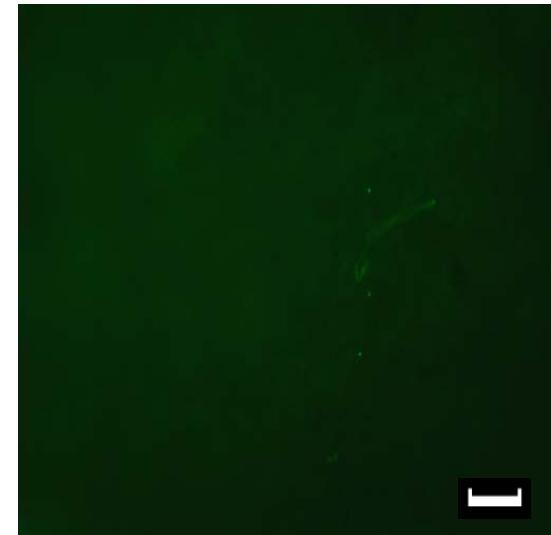
## Preliminary – Planktonic MRSA removal



Untreated  
control



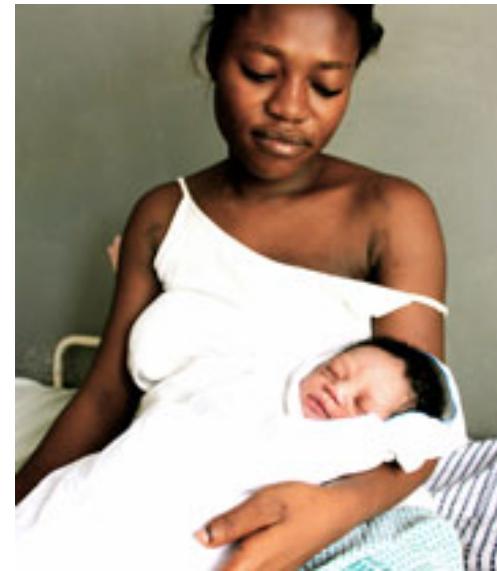
Saline control



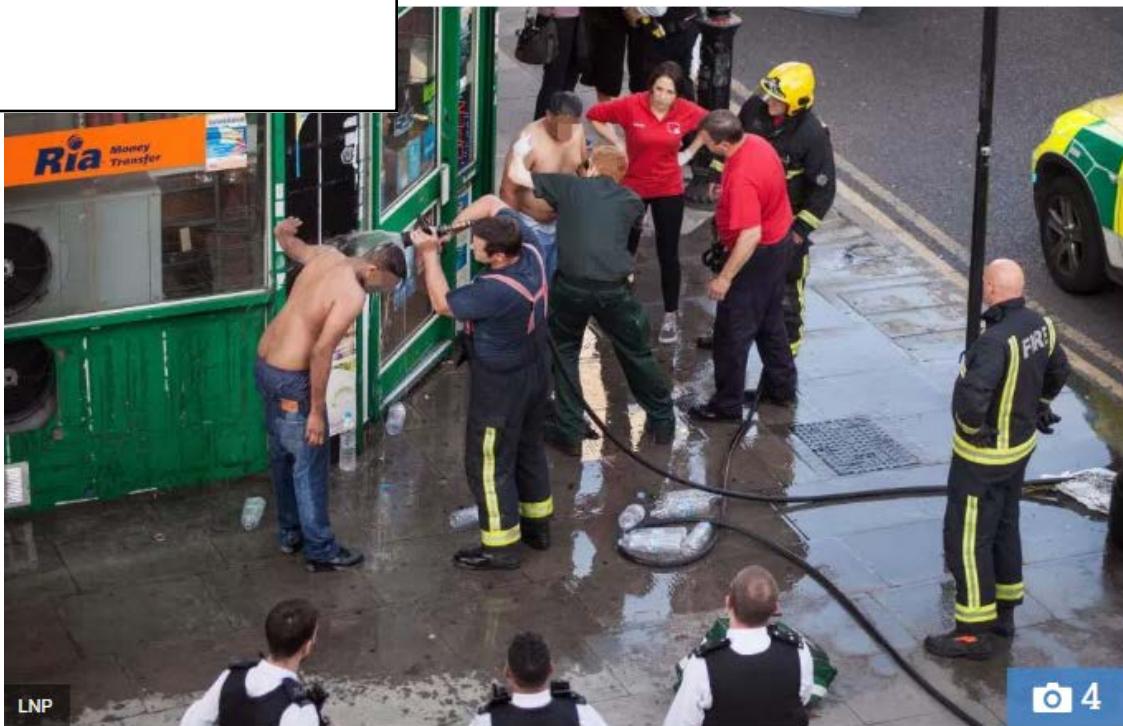
Saline and UAS  
(1 minute)



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

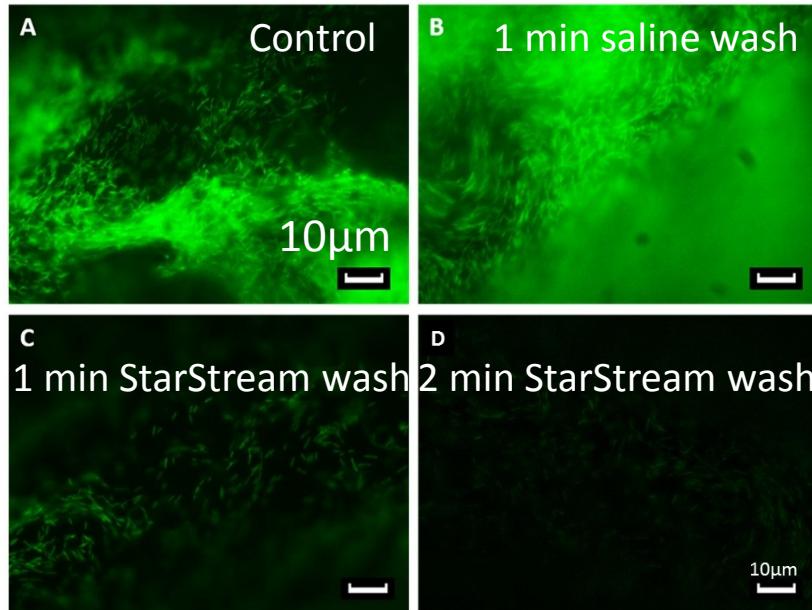


Firefighters use the hose from their engine to douse the young man in water

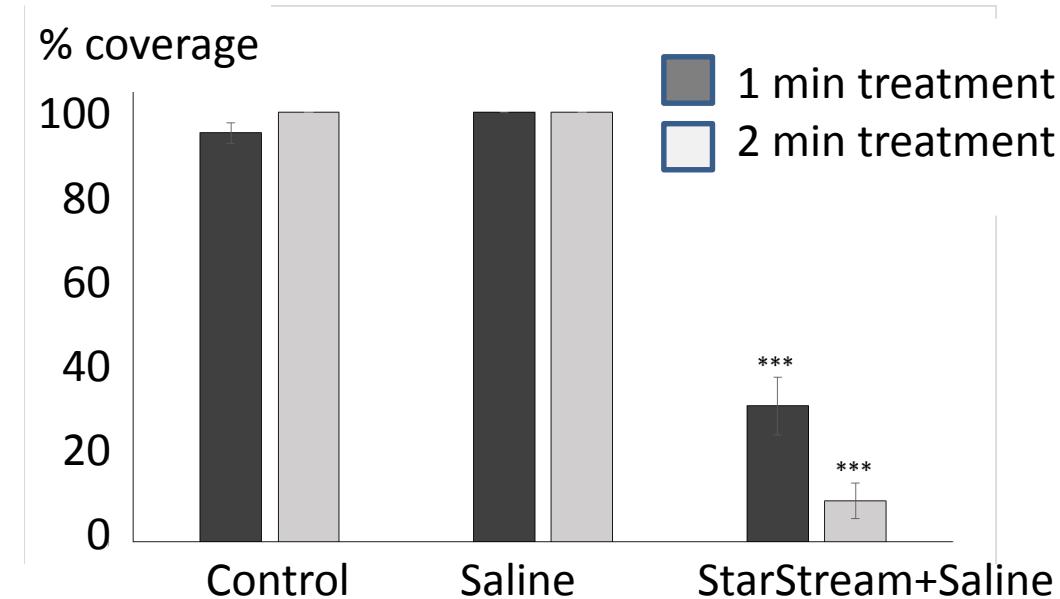


Firefighters use the hose from their engine to douse the young man in water

# Biofilm removal – pig trotter



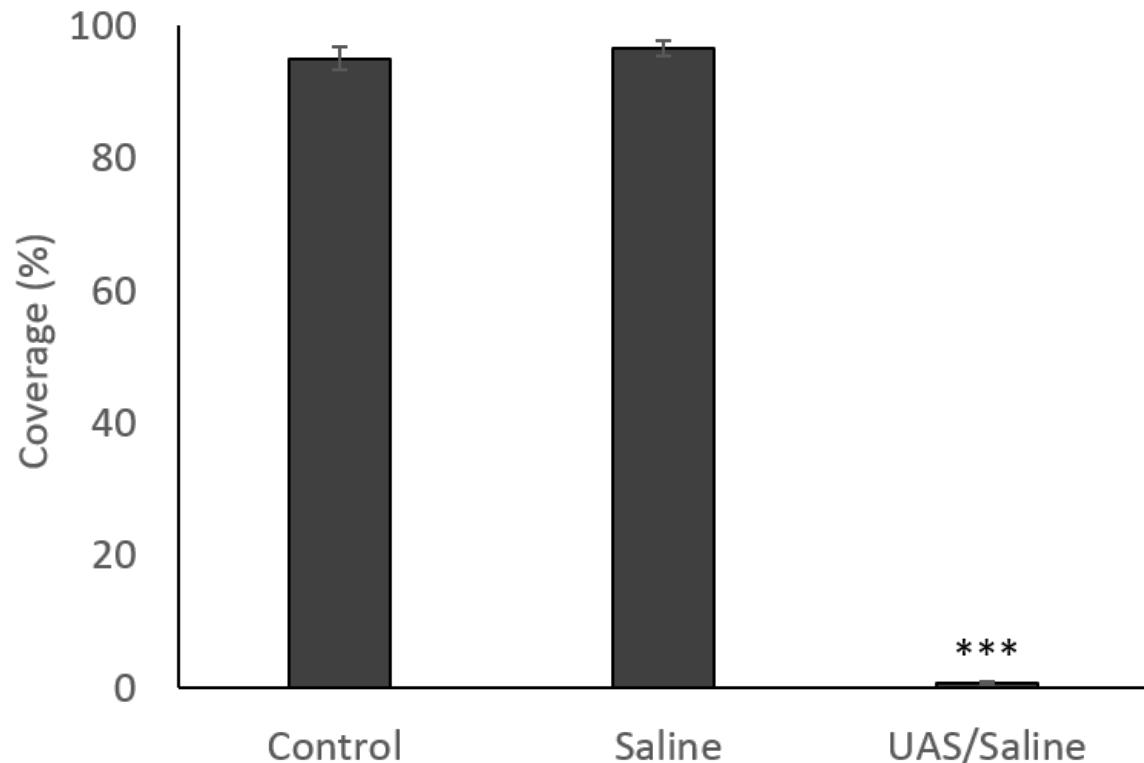
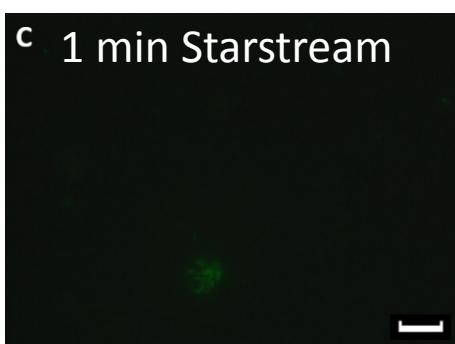
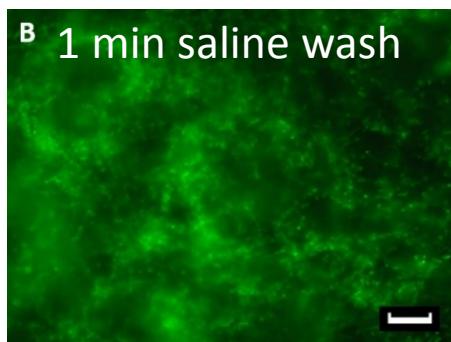
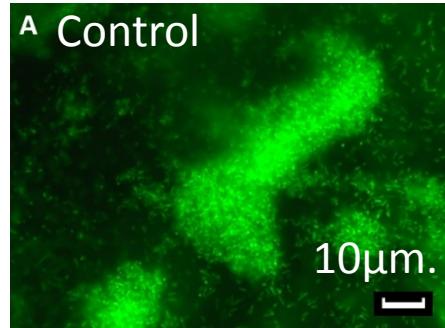
Direct EDIC/EF micrographs of GFP tagged *Pseudomonas aeruginosa* pMF230.



Error bars represent SEM (N=3), One way ANOVA/Tukey post hoc test \*\*\* =  $p \leq 0.001$  compared to non-treated controls.

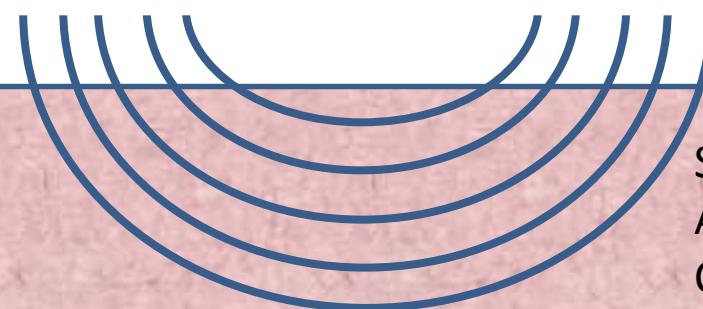
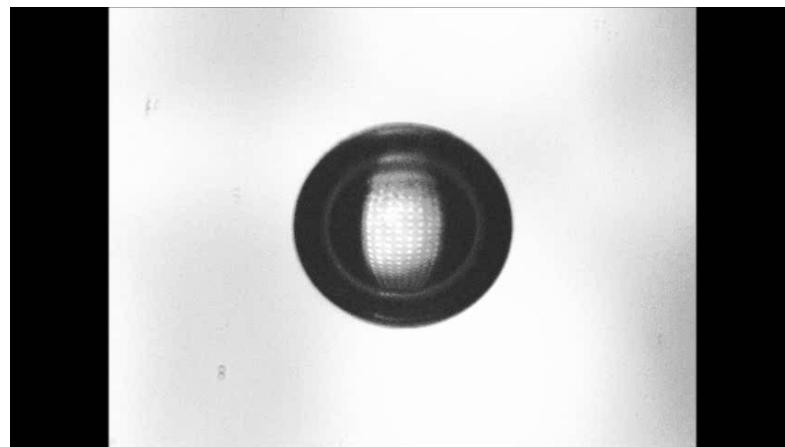


# Biofilm removal – EpiDerm™ FT



Error bars represent SEM (N=3), One way ANOVA/Tukey post hoc test \*\*\* =  $p \leq 0.001$  compared to non-treated controls.

*StarHealer*



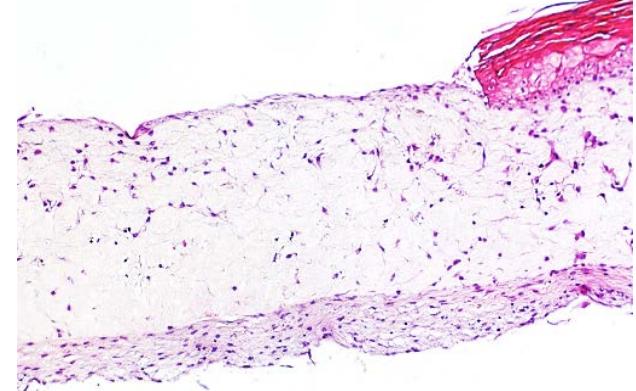
Shear  
Acoustic waves  
Convection



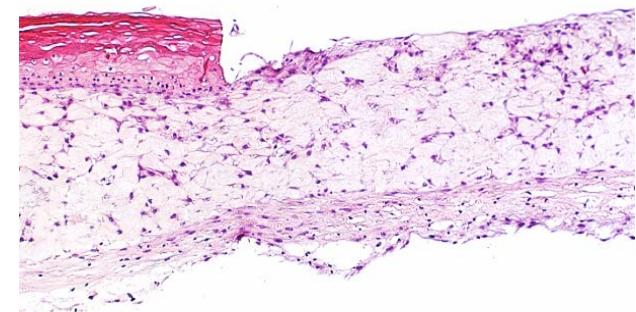
StarHealer wash with cold water for 2 mins after injury, then wait 7 days

Haematoxylin and Eosin (H&E) stained sections from the Epiderm full thickness wound models

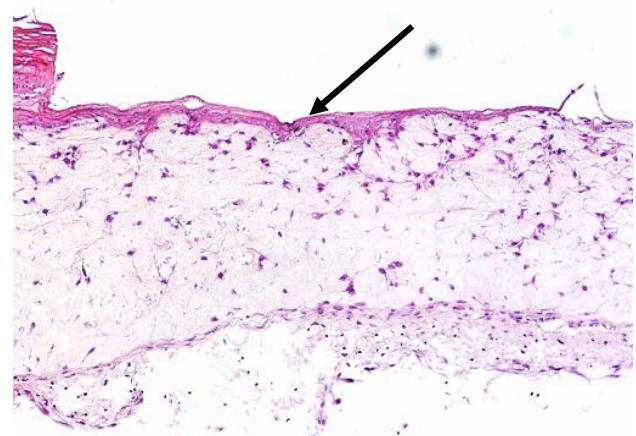
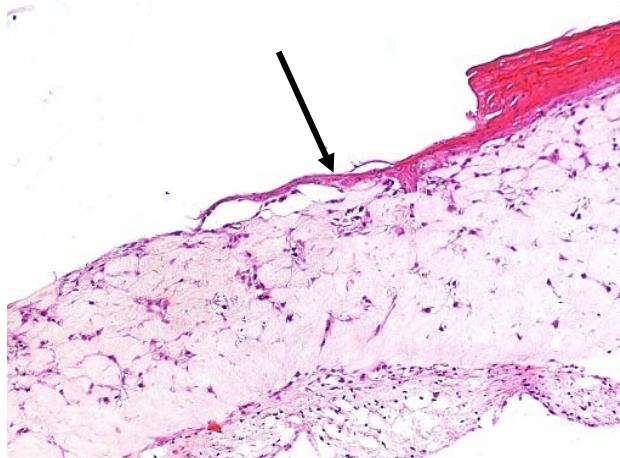
Example H&E stained sections (4 $\mu$ m) taken from the EFT wounds 7 days post cleaning



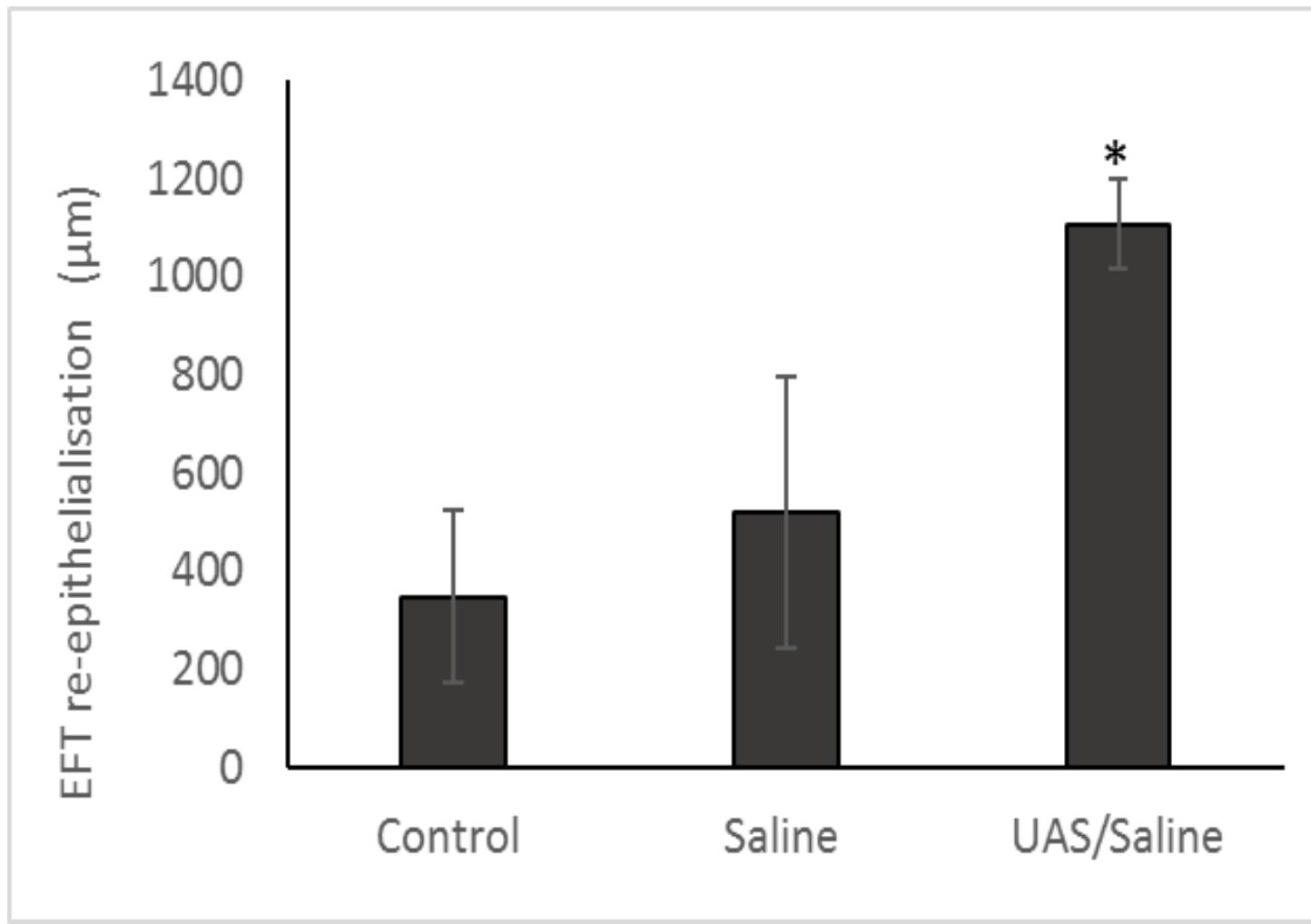
Control (No treatment) +7d



Saline (2 min) +7d



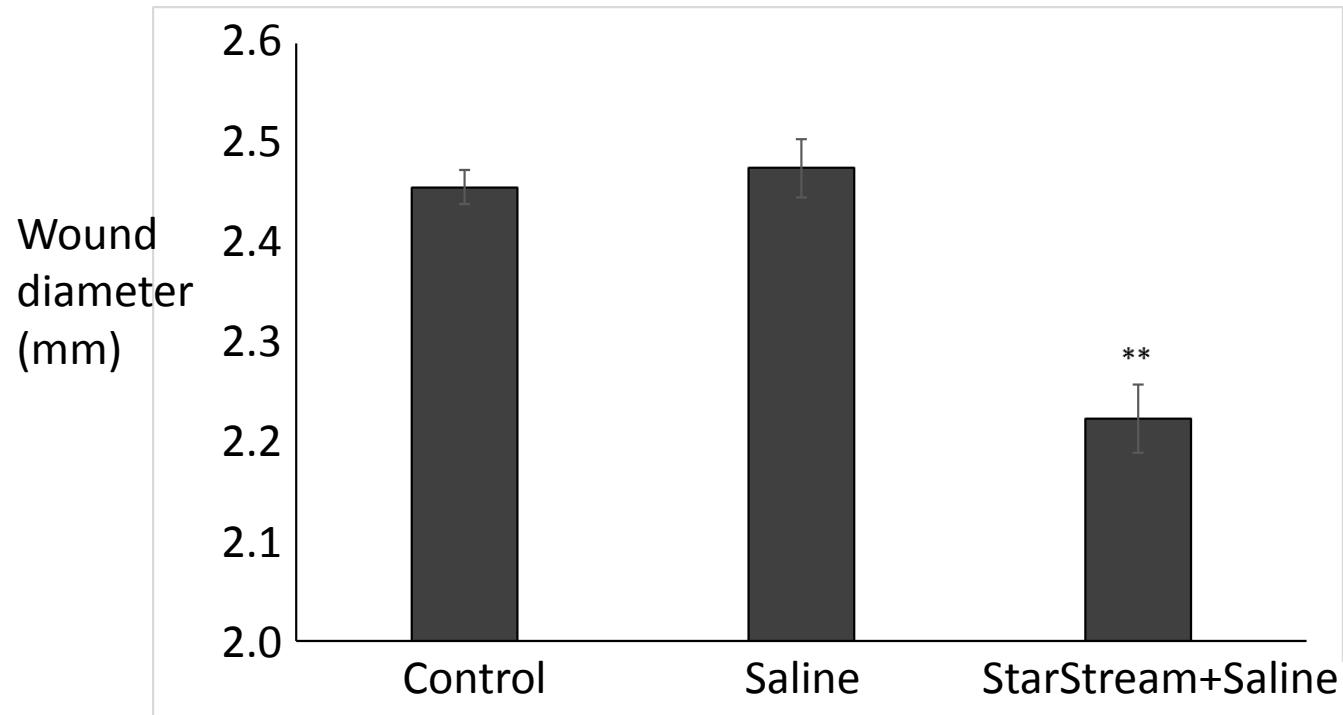
UAS (2 min) +7d



Re-epithelialisation in the Epiderm full thickness wound models, image analysis results demonstrating the distance of re-epithelialisation from the wound edge 7 days post cleaning

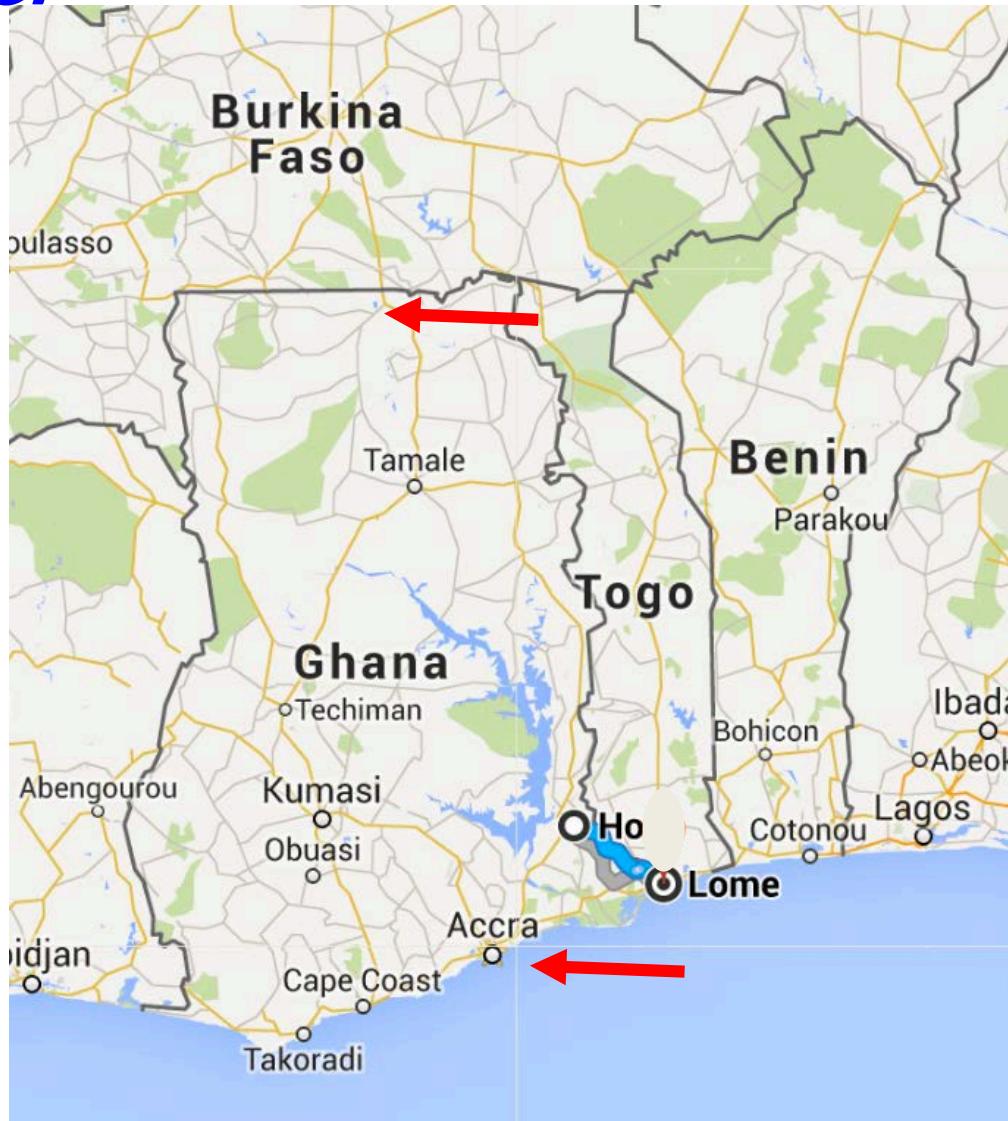
*Error bars represent the standard error of the mean (N=3), T-test demonstrated \* = p ≤ 0.05 when compared to the non-treated controls.*

# Improved healing rate in StarStream treated wounds.



Wound diameters 7 days post cleaning; with no treatment (Control), after a 2 min saline wash at a flow rate of 2 L/min (Saline) and after a 2 min UAS/Saline treatment at a flow rate of 2 L/min (UAS/Saline). Error bars represent the standard error of the mean (N=3), One way ANOVA/Tukey post hoc test demonstrated \*\* =  $p \leq 0.01$  when compared to the non-treated controls.

# *StarHealer*



border  
between  
Burkina  
Faso  
and Togo

near  
Accra

# Surgical Site Infection

- Cause of increased healthcare cost and patient suffering
- Disproportionate burden for low and middle income countries<sup>1</sup>
- Treatment difficult and long duration
- This new ultrasonic technology could improve treatment

<sup>1</sup> Surgical site infection after gastrointestinal surgery in high-income, middle-income, and low-income countries

*Lancet Infectious Diseases* 2018

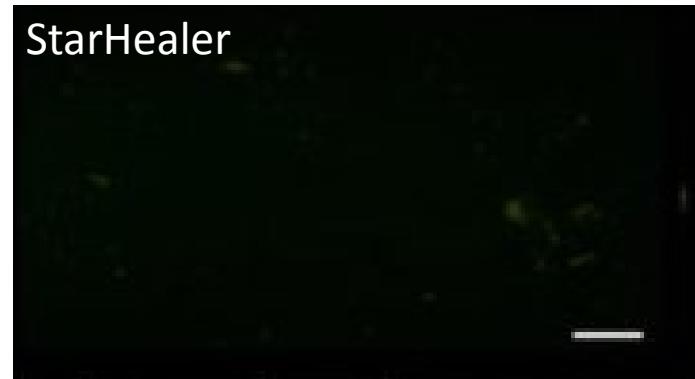
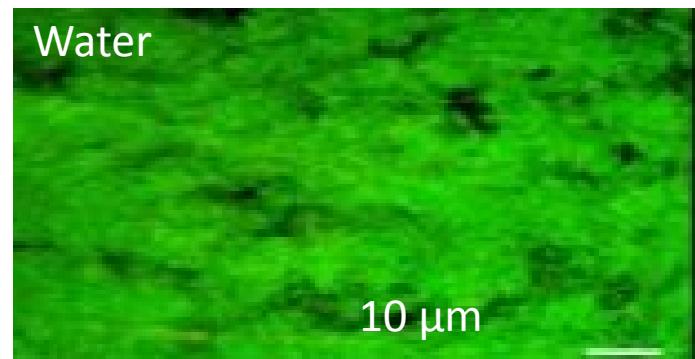
[https://doi.org/10.1016/S1473-3099\(18\)30101-4](https://doi.org/10.1016/S1473-3099(18)30101-4)



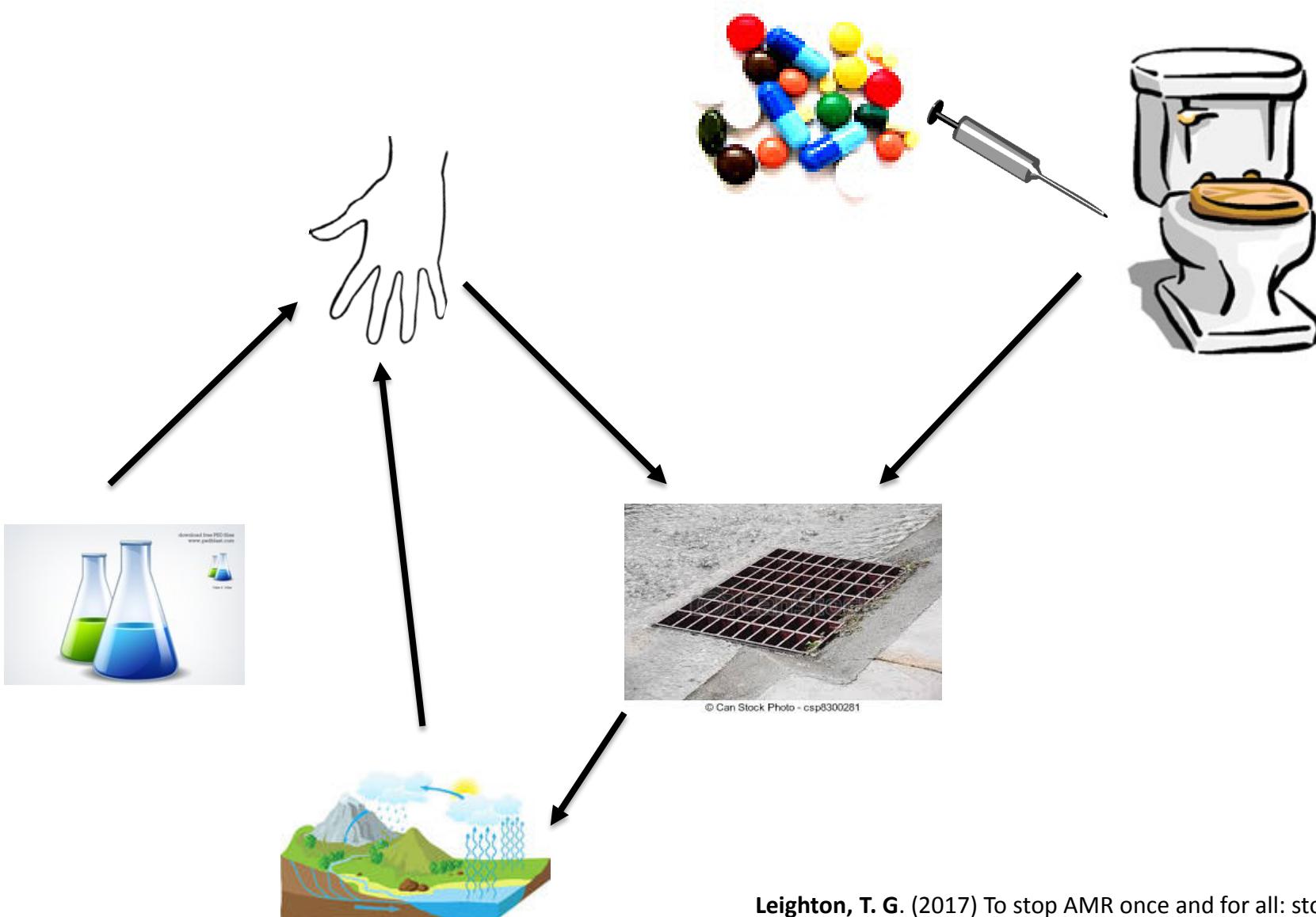
Surgical wound  
infection after  
abdominal surgery

# Superficial Bacterial Infections

- Infections on skin, mucous membranes, open wounds
  - Open traumatic wounds,
  - Burns,
  - Diabetic leg ulcers
  - Vascular Insufficiency Ulcers
- Bacteria exist in protective biofilm
  - makes treatment difficult
- This new ultrasonic technology can remove biofilm
- No mechanism for AMR



# Handwashing and wound cleaning



Leighton, T. G. (2017) To stop AMR once and for all: stop killing the bugs! EPSRC Blog: <https://www.epsrc.ac.uk/blog/stopamr/>