Cold water cleaning in the preparation of food and beverages

The power of shimmering bubbles

Timothy G. Leighton, Institute of Sound and Vibration Research, University of Southampton

On its own, cold (e.g. room temperature) water is often not an effective cleaner. If the addition of chemicals and heat is not allowed, then there have traditionally only been three ways of cleaning with cold water: soaking, jet washing, and the ultrasonic cleaning bath.

Soaking relies on diffusion. It is, therefore, slow, can leach nutrients, is unable to deal with contaminants whose attachment does not weaken by immersion in water, has poor effectiveness against contaminants in cracks and crevices and may even benefit the growth of some microbial contaminants. Because it adds a mechanical component to the cleaning action, jet (or power) washing is very effective against smooth, robust targets, but has limited effect in penetrating small (e.g. diameters less than 50 microns) crevices and can damage even relatively tough products like car paintwork.

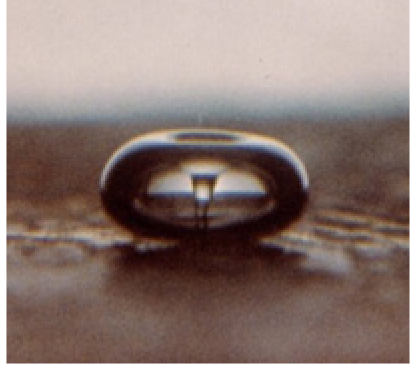

Figure 1. A bubble collapses under an oscillating pressure field. Instead of remaining as a sphere as it collapses, the presence of a solid (brown) wall at the base hinders flow there, so the liquid at the upper wall of the bubble moves faster, accelerating to form a high speed microjet. Image courtesy Prof. L A Crum.

Ultrasonic cleaning baths also add a mechanical action to cold water cleaning. They cause bubbles to collapse, with high speed microjets passing right through the centre of the bubble towards the solid on the other side (Figure 1). The impact of the jet with the solid causes high pressures and users of ultrasonic cleaning baths often test whether their devices are still working by submerging aluminium cooking foil in them and checking that tiny pits can be seen when the foil is then held up to a light. The bubble activity in ultrasonic cleaning baths therefore causes erosion and, furthermore, the gas within the bubble can become so compressed for a short time that it can generate free radicals, highly reactive species which in the food industry can lead to off-tastes. Ultrasonic baths have drawbacks : they can only treat items small enough to fit within them; then keep that item in a 'soup' of contaminated material removed from them, which can adhere to the item when it is removed from the water.

None of the above technologies, therefore, come without drawbacks. A new ultrasonic technology, the Ultrasonically Activated Stream (UAS; Figure 2), is incorporated into a rinse, so that removed contaminants are washed away (as with the jet washer) and the target does not sit in a contaminated 'soup' (as with soaking and the ultrasonic cleaning bath). It incorporates a mechanical action, so does not rely on slow diffusion, like soaking, but that action is very gentle. For example, the pressures in the water stream of UAS are 100,000 times less than the pressures in even the lowest powered jet washer. The mechanical action is produced by ultrasound, which is generated in a handheld conical device, resembling a trumpet horn in reverse (Figure 2). The water passes through this handheld horn and in doing so ultrasound and microscopic submerged bubbles are injected into the water stream. Ultrasound and bubbles pass down the stream onto the target to be cleaned (in Figure 2, a hand).

Figure 2. Professor Leighton demonstrates his invention by washing his hands with cold water and no soap.

The ultrasound causes the bubbles to clean the target, but not by violently collapsing them in the manner shown in Figure 1. Instead, the ultrasound stimulates the wall of the bubble to 'shimmer' (Figure 3), microscopic ripples on the bubble causing strong but localised shear in the liquid close to the bubble, which can remove contaminants through mechanical, not chemical, means. In effect, the bubbles become 'microscopic scrubbing machines'. The power of this mechanical approach is clear from Figure 4 (over page), a medical example, where a 20 minute soak in hydrogen peroxide is unable to clean away flesh from bone, but a 20 minute rinse under the new system's cold water is effective.

The device's bubbles have one further trick. It was pointed out, above, that several cleaning methods are poor at removing contaminants from cracks, crevices and pores. UAS's ultrasound automatically programmes the bubbles to seek out and penetrate these crevices, burying in whilst scrubbing away, to clean the places other cleaning methods do not reach – and all with just cold water. An example of this type of behaviour is shown in Figure 5, where a sticky contaminant is placed on a submerged block of glass, into which a cylindrical pore about the diameter of a mid-size human hair has been etched (Figure 5a). At the base of this pore is a sensor which records, by the graph shown at the base of each panel, how clean the base of the pore is. The red vertical line on the graph indicates the time corresponding to the movie frame above it. The contaminant layer is stable before the ultrasound is turned on (Figure 5a), but is rapidly removed from the flat upper surface of

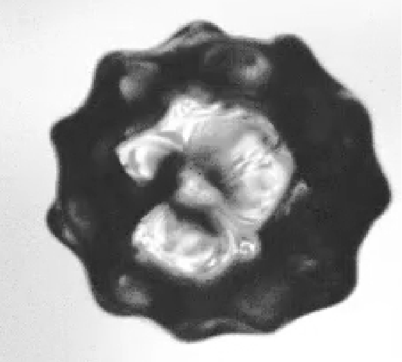

Figure 3. A bubble containing ultrasonically-induced surface waves which move rapidly over the bubble surface, 'scrubbing' the surroundings.

> **UAS's ultrasound automatically programmes the bubbles to seek out and penetrate these crevices, burying in whilst scrubbing away, to clean the places other cleaning methods do not reach – and all with just cold water.**

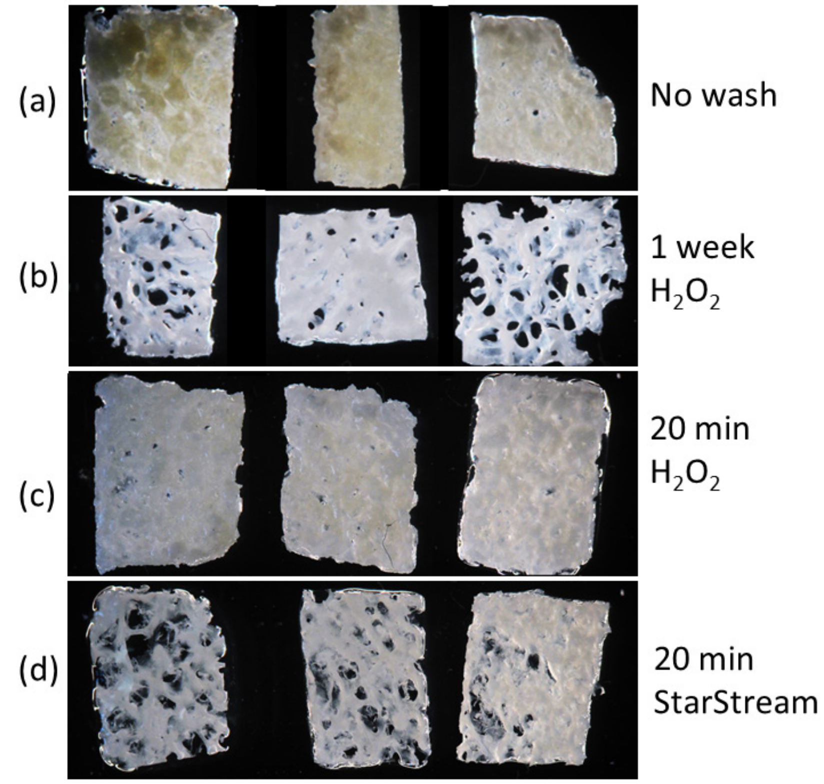

Figure 4. On the top row (a) four samples of trabecular bone (a porous honeycomb structure) contains unwanted white soft tissue within the honeycomb pores. This is usually removed prior to bone grafts to prevent rejection of transplants, by soaking for 1 week in hydrogen peroxide [row (b)]. Soaking for 20 minutes in hydrogen peroxide is not effective [row (c)]. However 20 minutes under the UAS system is effective at cleaning [row (d)]. From Ref. 3.

the glass when the ultrasound is turned on, making the water cloudy (Figure 5b). However the electrode shows that the base of the pore is still dirty, until the bubbles automatically find the pore and penetrate it (Figure 5c), their walls shimmering with ripples. The moment when they reach the bottom of the pore (Figure 5d) corresponds to the time that the electrode signal shows the pore to be clean.

This produces remarkable cleaning, without the use of heating, chemicals or solid abrasives which can damage the underlying substrate, and with excellent penetration of crevices. Figure 6 shows the removal of three types of dental bacterial biofilm from glass slides with castellation-like structures etched into them, demonstrating how only the new device penetrates to clean the crevices.

To demonstrate the versatility, Figure 7 shows the UAS technology removing the residue paper and glue from a jam jar label, and Figure 8 shows how UAS can clean mascara from the end of a 30 cm long tube. The application for the latter might be in the dispensing of beverage from a machine, where to prevent the sugary residue attracting microbes, the pipes are routinely flushed with chemicals. However, such flushing creates an off-taste that must be removed by flushing with beverage. The UAS technology allows pipe cleaning using just cold water.

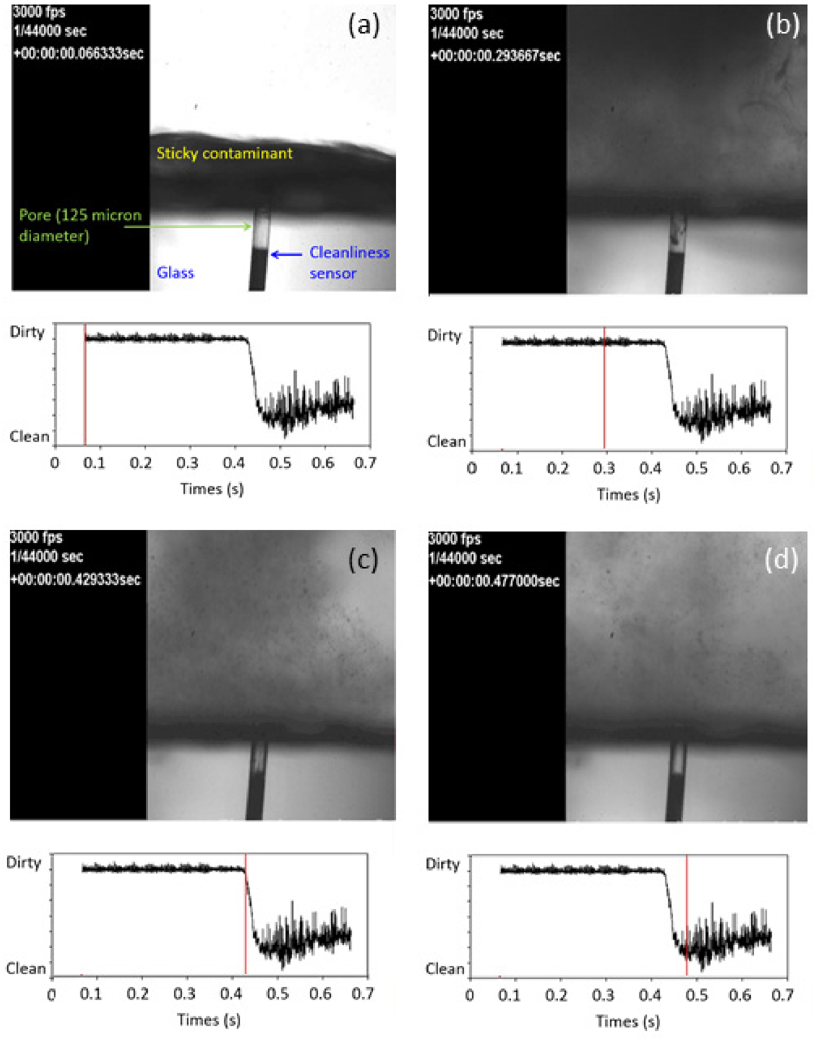

Figure 5. Four frames taken from a high speed movie filmed at 3000 frames per second. Each panel [(a) to (d)] shows, in the upper half, the movie frame, and in the lower half of each frame is the output of a platinum 'cleanliness sensor' which is placed at the base of a cylindrical pore (of diameter 125 microns) in the glass. For the artificial conditions of this visualization, the water is doped with chemicals that play no role in the cleaning (detailed in Ref. 4).

CONCLUSIONS

The new device described here is the first of a number of ultrasonic inventions which apply the power of shimmering bubbles to clean using just cold water. Others are designed to clean large, flat surfaces and some to penetrate constricted geometries. The potential is perhaps greatest in cleaning microbes. Every time we clean using a chemical (e.g. antimicrobial) attack to kill microbes on a surface, we eventually flush those chemicals down into the sewage, soil and water supply, which receive a dilute concentration of the killing chemical we used. Once in the wider environment, it kills off the weaker microbes from the gene pool, so that the genetic make-up of the reservoir of microbes in the

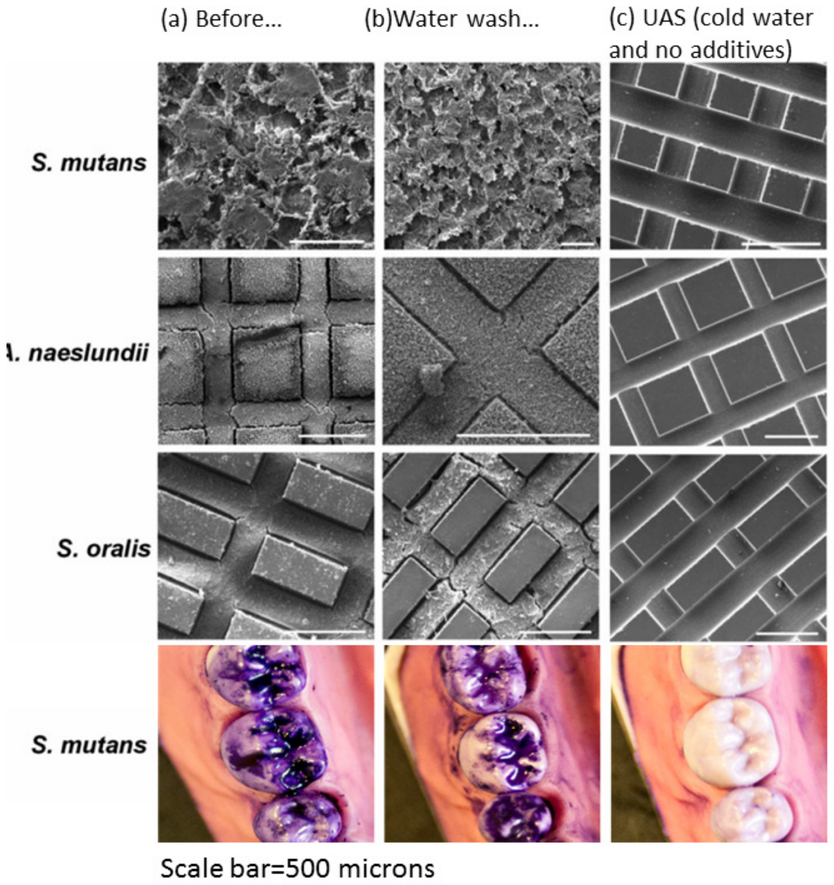

Figure 6. Three dental bacterial biofilms are (a) placed on machine-etched glass. (b) Ten seconds under a stream of cold water shows little visible cleaning, but (c) 10 s under UAS cleans more effectively. Similar results are seen in the lower row when Streptococcus mutans UA159 biofilms (made visible by crystal violet staining) are grown on molar teeth in a typodont training model. From Ref. 5.

Figure 7. Removal by the UAS of glue used to attach label to jam jar. The video of this is available at: https://www.youtube.com/watch?v=0H3ZE9IrgoQ.

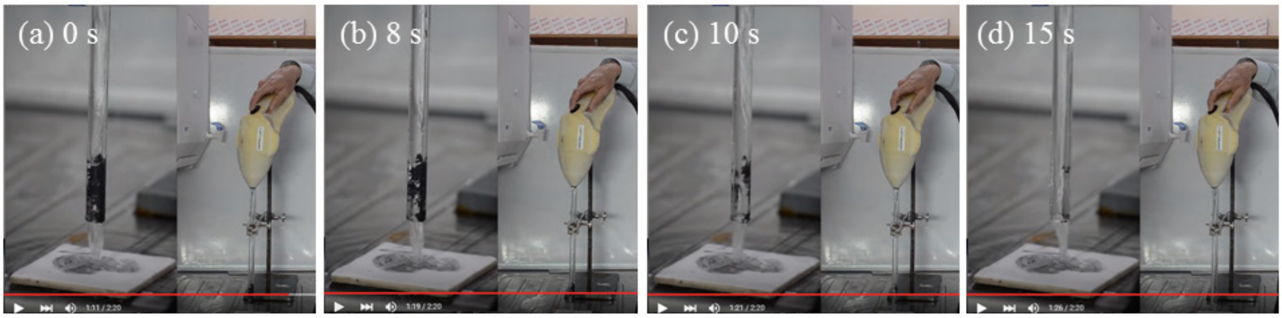

Figure 8. The base of a 30 cm long hollow glass tube is contaminated with dried-on mascara. Four panels from the split-screen video are shown, at (a) 0 s (just after cold water without ultrasound began to be projected down to the tube), (b) 8 s (just as the ultrasound was turned on), (c) 10 s and (d) 15 s. The video of this is available at: https://www.youtube.com/watch?v=g2qWOuNLB2A.

wider environment shifts to be more resistant to our chemicals. The most famous example of this is in the medical and veterinary arenas, where it leads to the development of ‘superbugs’ that are resistant to antibiotics, antifungals, antivirals, and the treatments we use against parasites. UAS technologies can be used to kill microbes, but they can also be used to detach them so that they return to the wider environment alive, so that we do not alter the gene pool there with our treatments. If we wish that to happen, then it means that the next time our technology, food, products, water pipelines etc. become infected, the microbes are no more resistant to being removed than the last time we removed contaminant. Resistance does not develop. ■

---

1 Leighton, T. G., Birkin, P. R. and Offin, D. (2013) A new approach to ultrasonic cleaning, Proceedings of the International Congress on Acoustics, Vol. 19, paper 075029 (2013) (4 pages) [DOI: 10.1121/1.4799209]

2 Leighton T. G. (2017) The acoustic bubble: Ocean, cetacean and extraterrestrial acoustics, and cold water cleaning. IOP Journal of Physics: Conference Series 797 (2017) 012001 (23 pages) (doi:10.1088/1742-6596/797/1/012001).

3 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. Cold water cleaning of brain proteins, biofilm and bone - harnessing an ultrasonically activated stream, Physical Chemistry Chemical Physics, 17, 20574-20579, (2015).

4 Offin, D.G., Birkin, P.R. and Leighton, T.G. (2014) An electrochemical and high-speed imaging study of micropore decontamination by acoustic bubble entrapment, Phys. Chem. Chem. Phys., 16(10), 4982-4989 (doi:10.1039/C3CP55088E).

5 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. and Stoodley, P. Removal of dental biofilms with a novel ultrasonically-activated water stream, J. Dental Research, 94(9), 1303-1309, (2015).

FIND OUT MORE

UNIVERSITY OF
Southampton

Institute of Sound and Vibration
Research, University of Southampton,
Highfield, Southampton, Hampshire
SO17 1BJ, UK   tgl@soton.ac.uk