WEEG NEWSLETTER Nov - Dec 2020

The newsletter is published monthly by the University of Southampton's Water and Environmental Engineering Group WEEG, and reports things of interest in this field worldwide, as well as ongoing undergraduate student and research work in WEEG itself.

We believe that water and energy are the most important topics worldwide for the next decades. Our work covers river and coastal engineering, water and wastewater and energy related to water.

Editorial: Cavitation is a well-known fluid flow phenomenon which occurs in low-pressure zones and can cause corrosion of materials and energy dissipation. But some other aspects of cavitation are not-so-well known:

Hydraulic Engineering International: *Cavitation*

We all know what cavitation is – in areas of low pressure, close to zero absolute pressure to be more accurate, vacuum bubbles pop up in water. When transported into areas of higher pressure, the bubbles collapse. This generates extremely high pressures which can damage concrete and metal surfaces. Cavitation occurs in turbines, ship's propellers, pumps and also e.g. on spillways. Fig. 1 shows cavitation damage to a spillway ramp.

Fig. 1: Oroville dam spillway

One way to reduce or prevent cavitation is to aerate the water, i.e. to introduce air bubbles. In zones of low pressure, the air can expand and thereby prevents the formation of vacuum bubbles. This however introduces an additional energy dissipation mechanism into the flow.

Sonoluminescence: During their collapse, the cavitation bubbles also produce noise, their temperature reaches around 5000 K and sometimes they even emit light. It has been reported that during high flows, the water on the energy dissipating structure of the Boulder Dam (Colorado, USA) cavitates severely. The water at the tailrace of the Errochty hydroelectric station in Scotland starts to glow. The glowing is just about visible during the day, but is very clear during the night, with a blueish colour. This effect appears to be related to sonoluminescence, the emission of light from gas bubbles in water which collapse when excited by sound waves.

Fig. 2: cavitation bubble emitting light

Ultrasonic cleaning: Cavitation is not just limited to fast flowing water (or objects which move very fast in water). It can be produced e.g. by introducing ultrasonic sound waves which superimpose, generating very low pressures during the wave trough of the sound wave. This effect is employed in ultrasonic cleaning, an area where Southampton's Institute for sound and Vibration Research (ISVR, www.southampton.ac.uk/engineering/research/centres/isvr.page) has a lot of expertise). The cavitation bubbles are very small, and collapse near the wall of the object so that surface dirt is removed.

Cavitation in nature: The pistol shrimp is a small shrimp, 30 to 50 mm long, of the *Alpheidae* group. It is characterised by having one disproportionally large claw, see Fig. 3. Also, the claws do not have a pincer-type end, but a two-part feature very much like the hammer of a pistol. A joint allows the hammer to move backwards into a right-angle position. When released, it snaps into the claw, generating a very fast flow, low pressure and subsequently cavitation bubbles.

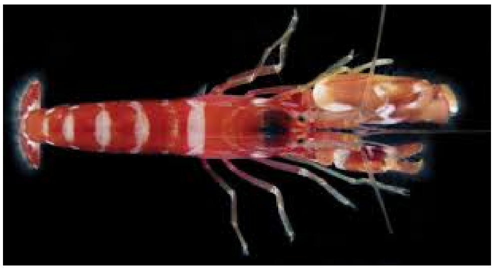

Fig. 3: The pistol shrimp

The bubbles are directed against prey or enemies, stunning or killing them when collapsing on contact over distances of up to 40 mm. The water jet and bubbles can reach speeds of 29 m/s, and create a signal with a duration as short as 1 millisecond! During collapse, the bubbles can reach a temperature of 8000 K. The collapse also creates a light pulse, although this is not visible to the naked eye. The sound generated by colonies of pistol shrimps is one of the major noise sources in the ocean, and can interfere with sonar and underwater communication.

Research topic: *VFA production*

Fermentation is well-known for producing wine, beer, lactic acid but other lines can make volatile fatty acids (VFA), the building blocks for a wide range of materials from plastics to aviation fuels. This important line of research builds on our strength in anaerobic digestion (AD), and provides another opportunity to contribute to the circular bio-based economy.

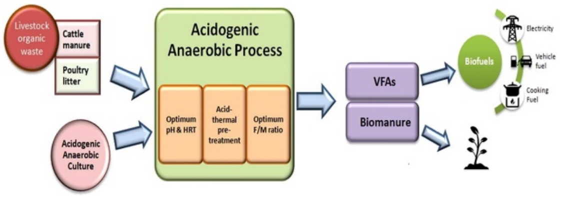

Fig. 4: Anaerobic digestion and VFAs

Feedstock composition can influence VFA profiles. Dr Yue Zhang and Dr Jerson Placido were funded by the British Council for work on VFA from protein-rich fish wastes in Colombia. Several of our PhD students have already found distinctive topics. Tararag Pincam is looking at combined VFA production and phosphorus recovery in municipal wastewater treatment. Maria Ramos Suarez is working on residual municipal solid waste (MSW), a recalcitrant material that is likely to be available whatever waste recovery strategies are adopted. Feni Amriani is studying macro-algae, a promising substrate due to its role in nutrient recovery from marine environments.

As anyone who has accidentally 'crashed' an anaerobic digester can confirm, making VFA is easy: the challenge is to develop an economically and environmentally sustainable process. Effective valorisation requires 3 key steps: pre-treatment of complex substrates, optimisation of fermentation conditions, and extraction of soluble organic acids. Pre-treatments are similar to those for AD or bioethanol production from lignocellulosic substrates, with little specific research on VFA. Manipulation of fermentation conditions can affect VFA yields and profiles: this is a very active line of work, although results are scatter-gun and need systematisation. The main bottleneck is VFA extraction, with a variety of approaches under investigation. These include adsorption, electrocoagulation, electrodialysis, esterification, gas stripping, liquid-liquid extraction, membranes, pervaporation and salting.

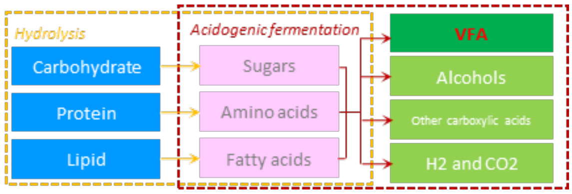

Fig. 5: VFA production

Membrane extraction and pervaporation are very promising, as they can be applied *in situ* to reduce product-induced feedback inhibition and thus maximise productivity. In previous work Dr Victoria Outram and Dr Zhang tested a porous membrane extraction method without chemical addition. This exciting development is being followed up in ***MSc projects*** and ***IPs***, with Part 3 student Najeeb Walizada aiming to integrate it in the fermentation process. The complex nature of fermentation broths and the potential for membrane fouling and damage is a challenge, especially when waste biomass is used; and there are issues of engineering scale-up. Microbial population studies can offer further insights: though a positive feature of this type of fermentation is the very wide range of organisms capable of carrying it out, making it an ideal candidate for the 'dirty biorefinery'.

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Jobs in water engineering:

This section gives you an idea of the type of work you can do when working in industry.

Civil and Environmental Engineering at Southampton University:

WEEG: the Civil and Environmental Engineering pathway offers the chance to deepen your knowledge in water-related areas, and gives you a better preparation for environmental engineering projects.

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Further information:

Our two Facebook pages provide a logbook of our laboratory activities:

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