**Institution: Coventry University**

**Unit of Assessment: 7**

**Title of case study: The impact of power ultrasound**

## 1. Summary of the impact

This case study describes over 30 years research by **Mason** and **Joyce** in high powered ultrasound. The research has delivered impact in the following four areas:

- **Health impacts** – by improving cancer care through the development of non-invasive cancer therapies.
- **Economic impacts** – developing business by working with commercial companies to develop and test new ultrasound-based products.
- **Impacts on the environment** – by reducing the environmental health impact of chemical and biological pollution in waste and potable water.
- **Impacts arising from public engagement activity** - by promoting understanding of the science and use of high intensity ultrasound.

**Beneficiaries** include cancer patients and medical practitioners, land owners, water companies, councils, commercial companies and the general public.

## 2. Underpinning research

Professor **Mason** has researched the application of high intensity ultrasound for over 30 years while at Coventry. **Joyce** completed her PhD at Coventry in 2003 and returned as a Research Fellow in 2007 to work with **Mason**. In contrast to low intensity diagnostic ultrasound which is used for medical scanning, ultrasound can be used at higher powers to treat cancer, purify water, clean the surface of printed circuit boards, or extract medicinal and other useful compounds from plants and algae.

Research into therapeutic applications of ultrasound at Coventry dates back decades [1] with two major research thrusts in this area. The first relates to the use of focused ultrasound as both a direct non-invasive treatment for the removal of solid carcinomas and also as a method for targeted drug delivery [2]. As the name implies, the non-invasive treatment of cancer avoids the need for a surgical operation to remove carcinomas and hence reduces patient trauma and the risk of infection. A second research area, in the application of focused ultrasound, provides a method of targeting the release of encapsulated chemotherapy agents directly at the site of a carcinoma [3]. This reduces the side effects associated with the more general delivery of drugs through the bloodstream.

Ultrasound also offers a cleaner and greener alternative to many existing technologies for environmental remediation. The powerful collapse of acoustic cavitation bubbles in water generates hydroxyl radicals that can oxidise chemical pollutants and this, together with the intense localised shear forces produced, can also destroy biological contamination through weakening or direct rupture of the cell walls [4]. For many years **Joyce** and **Mason** have used ultrasound either alone or in combination with other technologies e.g. UV light, catalysts and biocides for water remediation. More recently they have addressed two specific types of chemical and biological contamination. Firstly, the research used a combination of ozone and ultrasound to remove chemicals capable of affecting the hormonal activity in fish and mammals known as endocrine disruptors [5]. The second area involves the control of biological contamination in the form of algae, particularly blue green varieties (cyanobacteria), which present a serious risk to human health from the toxins which they produce [6].

**Mason** and **Joyce** also carried out research into the use of ultrasound to reduce the need for harmful chemicals in manufacturing and to improve the efficient extraction of valuable products from algae. The leMRC funded-research (£208,415) explored the preparation of the surface of printed circuit boards using ultrasound in place of harsh chemicals during manufacturing. This work showed that the process was cost effective and, more significantly, replaced the caustic chemicals originally used, with water. **Joyce** and **Mason** were also members of a consortium of 13 UK universities funded (£106,650) by the Carbon Trust as part of the Algae Biofuels Challenge. **Joyce**

and **Mason**'s contribution was to develop cost effective techniques to extract oils and valuable co-products from algae using ultrasound and ionic liquids. This research identified that ultrasound can be used to improve significantly the efficiency of the extraction process.

## 3. References to the research


1. **Mason**, T.J. (1994). Free radicals and ultrasound in chemistry and medicine. *Ultrasonics Sonochemistry, 1*(2), S131-S132 (Impact Factor: 3.708, Citations 3)
2. Yu, T., Wang, Z.,& **Mason**, T.J. (2004). A review of research into the uses of low level ultrasound in cancer therapy, *Ultrasonics Sonochemistry*, *11* (2), 95-103. (Impact Factor: 3.708, Citations 101)
3. Pavlov, A.M., Saez, V., Cobley, A., Graves, J., Sukhorukov, G.B.,& **Mason**, T.J. (2011). Controlled protein release from microcapsules with composite shells using high frequency ultrasound - potential for *in vivo* medical use. *Soft Matter, 7* (9), 4341-4347. (Impact Factor: 3.909, Citations 12)
4. **Joyce**, E., Phull, S.S., Lorimer, J.P., & **Mason**, T.J. (2003). The development and evaluation of ultrasound for the treatment of bacterial suspensions. A study of frequency, power and sonication time on cultured *Bacillus* species. *Ultrasonics Sonochemistry, 10* (6), 315-318 (Impact Factor: 3.708, Citations: 75)
5. Capocelli, M., **Joyce**, E., Lancia, A., **Mason**, T.J., Musmarra, D., & Prisciandaro, M. (2012). Sonochemical degradation of estradiols: Incidence of ultrasonic frequency. *Chemical Engineering Journal, 210*, 9-17 (Impact Factor: 3.691, Citations 2)
6. Wu, X., **Joyce**, E.M.,& **Mason**, T.J. (2011). The effects of ultrasound on cyanobacteria. *Harmful Algae, 10* (6), pp. 738-743. (Impact Factor: 3.953, Citations 5)


### Key Funding


- *"The evaluation of sonochemical techniques for sustainable surface modification in electronic manufacturing"* IeMRC £208,416 funding (PI **Mason**, Oct 2006-Oct 2009).
- *"Algae Biofuel Challenge"* Carbon Trust £106,650 (PI **Joyce**, Oct 2010–December 2011).
- The drug delivery research has been funded through a number of charitable donations for a total of £10,000 (Carol's Smile, Charles and Elsie Sykes Trust and the Reuben Foundation) (PI **Mason**, Start 2012 ongoing).
- Cooperation with China was assisted by a Sino-British Fellowship (£8200) supporting Xiaoge Wu (Project title: *Algae bloom control in natural water bodies*) (PI **Joyce**, 2012-2013).


## 4. Details of the impact

**Mason**, and more recently **Joyce**, have made a major contribution to the research in high-powered ultrasound and have taken their research findings beyond the laboratory to create impact in health, environment, economic and public engagement.

### Health impacts

Professor Feng Wu (leader of the Clinical High Intensity Focused Ultrasound (HIFU) unit at Churchill Hospital, Oxford) has stated that "… ***Mason*** *was instrumental in introducing High Intensity Focused Ultrasound technology to the UK in 2002. As a respected professional figure and research leader,* ***Mason*** *was responsible for establishing contacts between UK and Chinese clinical units and facilitated negotiations for the introduction, establishment of clinical trials and delivery of the equipment to the UK. He also provided advisory services to researchers at Chongqing Medical University and Chongqing Haifu Ltd in order successfully to communicate their clinical trial results. He played an integral part in securing the very first operational High Intensity Focused Ultrasound equipment to be delivered from China to the Western world*" [a]. This featured in the Research Councils UK 2011 publication "Big ideas for the future" [b].

### Impacts on the Environment

**Mason** and **Joyce**'s position as experts in the ultrasonically assisted purification of drinking and wastewater in municipal systems has led them to provide advisory and consultancy research services to two companies in Germany in the wastewater treatment sector.

In the first instance, Professor Uwe Neis (Ultrawaves GmbH) stated that **Mason**'s work regarding the practical application of ultrasound technology and his cooperation in disseminating advances in sonochemistry through a series of conferences in the second half of the 1990s were of fundamental importance [c]. He stated they informed the development of the approaches that Neis introduced to the German market and which are currently operational in over 150 locations around the world. According to Neis, Ultrawaves, founded in 2001 in Germany, and with subsidiaries in the UK and in the Baltic states, has become a world leader in the market for ultrasound-based treatment of water, wastewater and biomass. The technology developed by Ultrawaves takes into account advances in the practical application of ultrasound technology developed at Coventry University which has allowed the company to steadily grow since 2001 to a current yearly turnover of €2 million.

Ultrasonic Systems GmbH stated that collaboration with **Mason** to test the combined ultrasound with ozone technologies previously developed at a start-up stage were of fundamental importance in establishing a successful business [d]. **Mason**'s input was to take the 4-inch prototype testing machine that Ultrasonic Systems currently uses and test it in various ways in his laboratory. Dr Ulla Poeltsch, Director of the company stated that the testing and validation research that Coventry conducted and published was crucial as it showed that the technology was independently validated by a world-leading group. Furthermore, **Mason** went on to help them develop their own 4-inch prototype which has allowed Ultrasonic Systems to pilot test solutions for clients before they have to commit to buying the large-scale system. Thus small-scale ozone units, developed with the Unit principally for enabling piloting of larger projects, have proved to constitute a separately marketable product.

In addition, **Mason** has taken the experimental work on control of algae from the laboratory out to a local test site, through cooperation with Coventry City Council and Aquatic Plant Management. Over the last year a local park lake has been monitored for natural algal growth and subsequently ultrasonic equipment will be installed. This project will monitor the effects of ultrasound for one year followed by the same period of monitoring in the absence of ultrasonic treatment. As Mark Yates of Coventry City Council stated "*… using ultrasound to thwart the growth of algae in ponds will prevent considerable threats to public health". Although the study is still in an early stage, initial laboratory based results indicate that ultrasound will significantly reduce the amount of algae and hence the health risks to humans and animals as well as the environmental damage cause by mechanical skimming and disposal of the algae. Yates, stated that "the ultrasound technology developed …will circumvent the use of environmentally harmful chemical algaecides, which endanger wildlife and contaminate the surrounding environment by leaking in to the soil*".

**Economic Impacts**

Through sustained relationships, the group has contributed to validating, testing and developing new methods of applying ultrasound technology in different sectors. The significance for the partner companies varies from small inputs such as testing existing processes, to more significant impacts that have resulted in new companies being formed, global markets opened, and the accrual of both economic and environmental benefits.

**Joyce** and **Mason** have also been involved in the formation of multidisciplinary partnerships supporting a number of SMEs in their research and development functions, thus sustaining the SMEs' competitiveness. Key in these projects is the knowledge exchange between partners, SMEs and Coventry University, allowing partners access to scientific expertise and University facilities. Examples of SMEs involved in such research include Chestech Ltd (UK) and Dioxi Ltd (UK) in addition to Ultrawaves GmbH (Germany) and Ultrasonic Systems GmbH (Germany) mentioned in the earlier section on impacts on the environment.

Jonathan Sellars of Chestech Ltd stated his company lacks an R&D division, so that collaboration with **Mason** and **Joyce** allowed them to address particular customer problems. An example is the case of the improved and greener electroless coating technology for GPS antennae. This technology is sold to global companies such as TomTom and Garmin through Sarantel. The flexibility and quality of Coventry University's work allowed the company to retain and expand their market share.

In some cases the work of **Mason** and **Joyce** has helped companies in deciding not to proceed with ultrasonic technologies. Thus Dioxi Ltd was interested in using ultrasound-enhanced ozone

fogging technologies as a new way of sanitation for hospital rooms. After preliminary trials **Joyce** and **Mason** advised Dioxi Ltd that ultrasound would not be an economically feasible method thus preventing economic loss. As Bray, Dioxi Ltd, stated the "*…research has been fundamental in correctly testing the bacteriological impact of their technology and will inform its future development. **Joyce** and **Mason** had ideas about where the technology could be applied in the livestock sector and this has enabled the company to move into a new market*" [e]. This shows that collaborating with **Joyce** and **Mason** has improved the company's ability to test business ideas independently and practically in order to develop a commercially viable product. There are numerous examples of **Mason** and **Joyce** and their team helping SMEs to benefit from their expertise. However, the research is not just limited to SMEs; their research has helped larger companies. For example, GlaxoSmithKline in the field of food technology, a long-time specialism at Coventry, and Sibelco in terms of mineral washing.

It can be argued that without **Mason**'s research and help, Chongqing Haifu Ltd's High Intensity Focused Ultrasound technology would not have established as quickly in the Western world as it has. There are now 20 Haifu units throughout Europe in four different countries. Therefore, **Mason**'s research and endorsement contributed to the business development of this global company by facilitating its access to new markets. According to Nick Yin, Chongqing Haifu Ltd., in the past 5 years the company has generated a cumulative turnover of €40 million from the sales of new machines, and from operating existing installations in Europe [f].

**Public Engagement**

**Mason** has been a passionate advocate for increasing public awareness of the science and the application of ultrasound. Over the years he has delivered numerous School and Public lectures to explain the benefits of this technology. The research of **Mason** and **Joyce** was selected as an exhibit in the form of an interactive exposition unit entitled "the Power of Sound" at the 2009 Summer Science Exhibition of the Royal Society, an event visited by more than 5000 people and widely covered by popular media throughout the UK [g].

**Conclusion**

Over the last 30 years **Mason** and latterly **Joyce** have undertaken research to explore the potential uses of power ultrasound to make an impact in terms of it use in health, environmental protection and economic benefits. In addition, both have contributed to public engagement by increasing the awareness of science and in particular the use of power ultrasound to improve and maintain the environment by making processes cleaner, more efficient and safer.

**5. Sources to corroborate the impact**


a) Endorsement by Leader of the Clinical High Intensity Focused Ultrasound (HIFU) unit at Churchill Hospital, Oxford

b) Research Councils UK 2011 "Big ideas for the future" http://www.rcuk.ac.uk/documents/publications/BigIdeasfortheFuturereport.pdf

c) Endorsement by Director, Ultrawaves GmbH

d) Endorsement by Director, Ultrasonic Systems GmbH

e) Endorsement by Director, Dioxi Ltd

f) Endorsement by Manager of International Department, Chongqing Haifu Ltd

g) Royal Society Summer Exhibition, London, UK, The Power of Sound http://royalsociety.org/summer-science/2009/power-of-sound