UCD Impact Case Study

# Gas Hydrates – a Potential New Fuel Source or a Cause of Mass Extinctions?

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ACADEMIC TECHNOLOGICAL ECONOMIC

SCIENTIFIC ENVIRONMENTAL

## SUMMARY

Niall English has researched ice-like, crystalline solids called gas hydrates for more than 20 years. These block gas pipelines and form naturally in the permafrost and in sea beds at the edges of continents. Over the past five of these he has worked closely with QUB microbiologist Professor Chris Allen and together they have established that microbes can affect the stability of natural gas hydrates. They have also postulated a tentative link between reverses in the earth's magnetic polarity, relatively sudden releases of methane in the past and their possible contribution to mass extinction events something known as the "Belfast hypothesis". This research is important because it helps inform the work being undertaken globally on climate change.

The research partners have also filed a joint patent application on behalf of their respective universities which controls the way in which certain proteins and particular peptide sequences (short chains of amino acids) can be used to regulate the growth of gas hydrates. This has potential value in the global $1 trillion a year wastewater treatment (WWT) industry, particularly in pipeline flow assurance by preventing blockage caused by hydrates, and the treatment of heavily polluted water. Their research, therefore, has contributed impacts at community, economic and environmental levels. They have also just been awarded a joint British-Irish Leverhulme-Trust grant for two years (2021-23) to take this research further, with a keen eye to regulating hydrate formation in large-scale industrial applications.

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## An Appetite for Knowledge

As a boy, Niall English was excited by the way that the answer to one question always led to another. Not surprisingly, that appetite for knowledge ultimately brought him to a life in scientific research. He obtained a degree in Chemical Engineering from UCD in 2000 and did a PhD on ice like, crystalline structures called gas hydrates, which he consolidated further whilst working as a research associate at the US DOE National Energy Technology Laboratory in Pittsburgh. During those early years, his research was into ways of using microwave fields to prevent hydrates forming in natural gas pipelines under certain temperature and pressure conditions.

But while hydrates may be a nuisance to the oil & gas industry, others see them as a future fuel source with vast potential. When plankton and fish die, they sink to the seabed and the carbon they contain degrades into methane. Under intense pressure and cold this gas forms gas hydrates.

Over 95% of the world's methane is contained in this form, either in the depths of the world's oceans or in Artic permafrost. In 2015, English was invited to join the management group of a European COST Action group designed to explore the potential of gas hydrates "as an economically feasible and environmentally sound" energy resource.

Arising from this, he began a working relationship with Professor Chris Allen, a cross-disciplinary microbiologist in the School of Biological Sciences at Queen's University Belfast. This has led the two researchers to explore a number of related aspects of gas hydrates – and even to arrive at some dramatic, albeit controversial, hypotheses – in four significant papers published over the past three years.

"Chris's interest in microbes led us to speculate jointly on whether microbes might affect and even regulate or control the stability, or otherwise, of natural gas hydrates," English says. Finding this speculation to be correct, they were then able to isolate one particular protein involved in the regulation of hydrate growth and began to explore that in more detail.

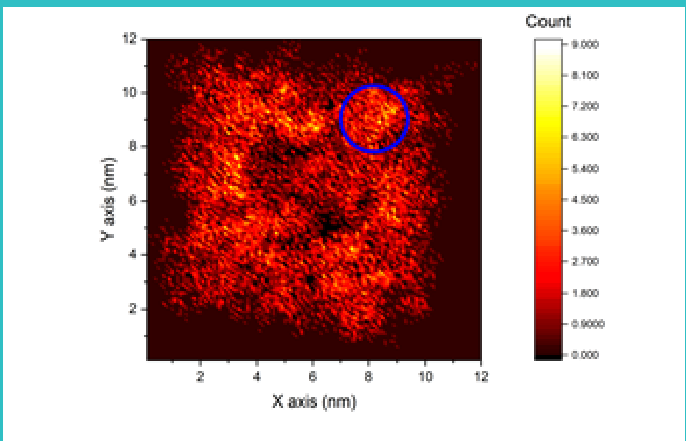
This work led them to make an imaginative leap into another related area of research. 'I was giving a talk on the ability of electromagnetic fields, in this case microwaves, to inhibit the formation of hydrates and to release established hydrates when Chris had a moment of inspiration. When I said the word 'electromagnetic', he immediately began to think about the possible effect of the Earth's magnetic field, which reverses its polarity over aeons of time."

## The Belfast Hypothesis

That brainwave led to the 'Belfast hypothesis', a tentatively proposed link between the effect of these reverses in the Earth's magnetic polarity on the release of methane trapped in hydrates and its possible contribution to mass extinction events of the past. "While we weren't the first to speculate this, we went on to undertake much more rigorous experiments and were able to correlate geologically historic fluctuations in the Earth's magnetic field with such events," English says.

The final piece of the jigsaw was exploring what role the chemical concept of "chirality" might play in this. This is a complex concept involving the 'left and right' handedness of molecules, such as amino acids. The researchers were keen to determine whether this might also be affected by the Earth's magnetic field.

Now an established cross-Border team, Allen and English have been applying for bilateral British/Irish funding – winning a Leverhulme-Trust grant and with others either under review or planned. 'If we are going to get more ambitious with this research, we're going to need more resources,' English says. They are also writing a comprehensive review of their work to date that will draw together many of these concepts. "We're going to link this quite boldly into James Lovelock's Gaia hypothesis, which is that biology regulates much of what's going on in terms of the Earth and its physical and chemical processes," English adds. "We expect that will also be regarded as controversial, but we feel have good evidence for proposing this at this stage."




Close to the action: Area of the 'Gaia' protein featuring the peptidic sequence of maximal hydrate-forming character

While this body of work has been of great academic interest, it is important because it also helps inform the work being undertaken globally on climate change. Methane has a warming effect about 25 times stronger than carbon dioxide, tonne for tonne, and the US Geological Survey has listed Arctic-hydrate destabilisation as one of the four most serious potential scenarios for abrupt, catastrophic climate change.

## 'This Process Has Now Been Triggered'

There is growing evidence that such destabilisation is already taking place. A recent international study, for example, observed high levels of methane are being released from sediment in East Siberia at six monitoring points in an area of 1,500 sq km about 600km offshore. "At this moment, there is unlikely to be any major impact on global warming, but the point is that this process has now been triggered," according to one of the research team, Swedish scientist Örjan Gustafsson.

This possibility has been the basis for a number of "Doomsday" scenarios of runaway warming that could tip the Earth towards a hothouse state. Although many researchers believe these scenarios are exaggerations, the work undertaken by Allen and English does indicate a valid scientific basis for believing hydrate may represent a real threat, and therefore demands further investigation. A better understanding of the causes of climate change is a critical element in efforts to ameliorate its negative effects. Allen and English hope to contribute an improved understanding of the possible role hydrate destabilisation plays in this and how its rate might be affected by both microbial action and changes in the Earth's magnetism. This will all help to better inform decision-making by policy-makers across the world. In this sense, therefore, their work is of huge economic and environmental importance.

## Significant Potential Impacts

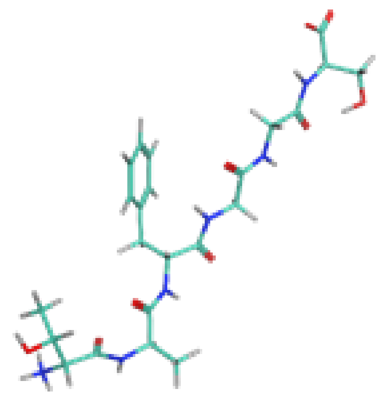
At a somewhat more prosaic, but still highly meaningful level, the two research partners filed a joint patent application on behalf of their respective universities in December 2018. The essence of this patent is that certain proteins and particular peptide sequences (short chains of amino acids) can be used to regulate the growth of gas hydrates.

This could be employed, for example, to promote gas hydrate growth for use in the global $1 trillion a year wastewater treatment (WWT) industry. "Heavily polluted water – it could be radioactive, full of animal fats or contain heavy metal ions from mining – would give conventional activated-sludge biological WWT plants severe 'indigestion', shall we say," English explains. "Introducing $CO_2$ or methane into that liquid separates out as gas and water trapped in the hydrate, leaving a firm sludge for subsequent safe disposal. At a molecular level, hydrate is the ultimate 'doorman'."

The patent sets out how hydrates can be made more efficiently. English, who is also a Chartered Engineer, has extensive experience in commercialisation, patents, IP, product development and already has two spin-out companies up and running – Aqua-B, which was developed to commercialise a new low-cost technology for the production of tiny bubbles (nanobubbles) within a liquid, and BioSimulytics, which provides software to predict the crystal structures of pharmaceutical compounds.

In focussing on WWT processes, a potential new spin-out for this work on heavily polluted water complements that of Aqua-B, where English is CEO, in lowering the cost of aerating conventional WWT sludge tanks. Development of such processes that improve the way in which heavily polluted sludge can be treated offers significant environmental as well as economic and social benefits.

Finally, Allen and English's finding on how magnetic fields regulate the action and catalytic activity related to short chains of amino acids has profound implications for controlling other chemical and physical processes beyond hydrate formation. It may even provide an understanding of the 'blueprints' for the evolution of life itself.




Knock 'em for six: the six-residue peptide sequence of greatest hydrate-forming propensity (with overlapping hydro-phobic and -philic regions)

## Research References

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