Maggel Deetlefs
Ken Seddon

Making the world safer
Ionic liquids at work

Hycapure-Hg™ are beads coated with an ionic liquid which are used to capture mercury and its compounds

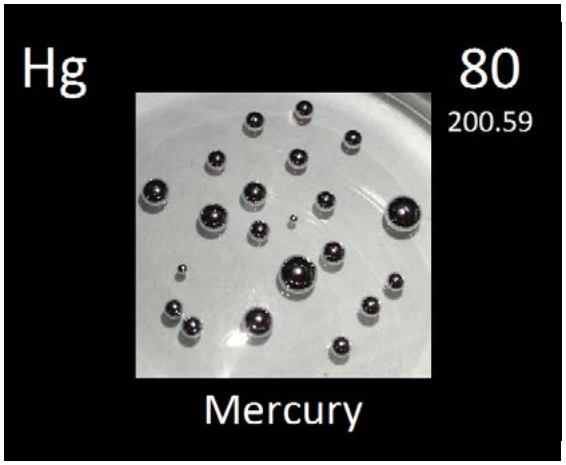
Key words
ionic liquids
mercury
pollution
natural gas

In the last issue of CATALYST*, we looked at the composition of ionic liquids and some of their uses. In this article, we describe how work at the Queen's University Ionic Liquid Laboratories (QUILL) in Belfast is reducing the amount of hazardous mercury entering the environment from the oil and gas industry.*

Natural gas remains an important source of energy. To keep up with our growing energy needs, new natural gas reservoirs need to be used, but they are often contaminated with toxic mercury. In a successful partnership, and in record time, QUILL have developed an innovative, ionic liquid-based technology to remove mercury safely from natural gas throughout the world.

Maddening mercury

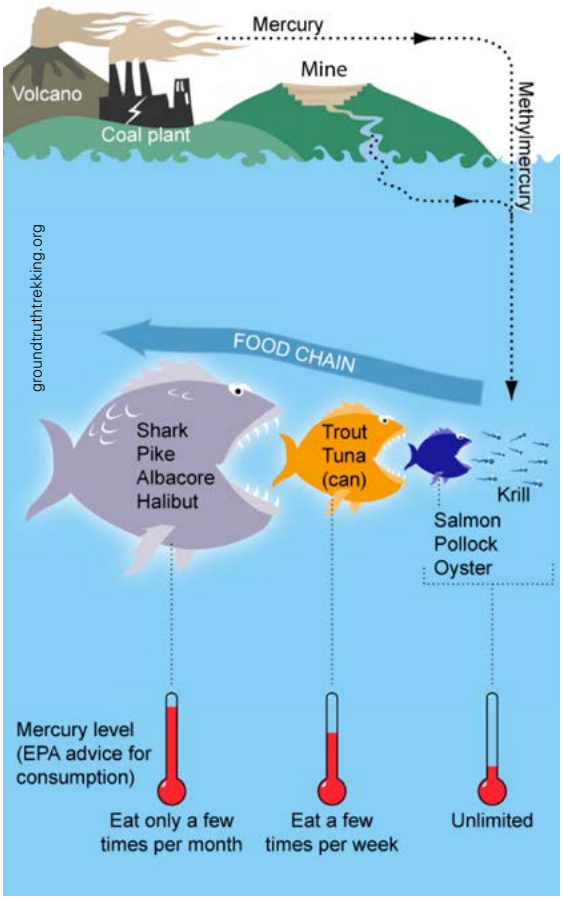
"Oh, you can't help that," said the Cat. "We're all mad here." – The Cheshire Cat in Alice's Adventures in Wonderland by Lewis Carroll



Of all the metals in the periodic table, the visual imagery of mercury is probably the most attractive and also the best known. It is a liquid under normal conditions and an important component of everyday items such as energy-saving light bulbs and laboratory thermometers.

But mercury has a dark side – it is an extremely toxic element in all its different forms. Mercury metal itself has a toxic vapour, but it can also chemically combine with other elements to form organic (carbon-containing) and inorganic (non-carbon-containing) compounds that are toxic too. In its metallic form, it causes 'madness'. Equally distressing, carbon-containing methylmercury found in fish and shellfish (see graphic opposite) causes Minamata disease, a neurological syndrome that affects the nervous system. Inorganic mercury compounds such as the salt mercury(II) chloride ($HgCl_2$) can be toxic to the kidney, stomach and intestines. The bottom line is that mercury, in all its forms, is extremely toxic and exposure to it must be reduced, or if possible, eliminated completely.

The Mad Hatter, as drawn by Sir John Teniel in Lewis Carroll's book Alice's Adventures in Wonderland. In the 19th Century hatters went 'mad' because they used mercury to add a shine to hats.



How methylmercury accumulates in fish.

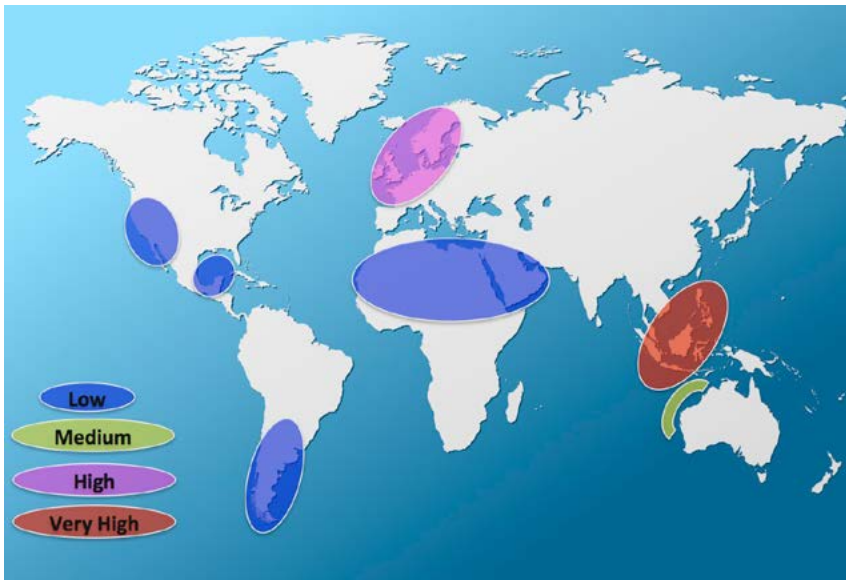
Mercury in natural gas

Alice: *"Would you tell me, please, which way I ought to go from here?" "That depends a good deal on where you want to get to,"* said the Cat.

A less well-known fact about mercury is that it occurs naturally in the Earth's crust – about 10% of all mercury emissions on Earth originate from environmental sources such as erupting volcanoes and natural gas reservoirs. Many different mercury compounds are found in natural gas reservoirs. These cause major health and safety problems for workers on plants, and can also severely damage plant equipment too.

A poignant example of the destructive result of mercury build-up occurred in Algeria in 2004 (see photo top right), when 27 people died in an explosion caused by mercury corrosion of the plant. So, because so many of us rely on natural gas as an energy source, ridding it of mercury is a vitally important global issue. The trouble is that this removal process has been fraught with difficulties and needed a better solution, especially in and around Malaysia, where mercury levels in gas fields can be extremely high (see map on right). Therefore, in a major industry/university team effort, PETRONAS (a national oil company based in Malaysia) and the Queen's University Ionic Liquid Laboratories (QUILL - based at the Queen's University of Belfast in Northern Ireland, UK) worked together to find an ionic liquid solution to remove mercury from natural gas feeds.

The Skikda liquefied natural gas plant in Algeria was destroyed by an explosion caused by mercury corrosion.



Maximum mercury levels in natural gas fields worldwide

Mercury capture using ionic liquids

"Nothing's impossible!" – The Doorknob

Ionic liquids are liquid salts – they consist only of positively-charged cations and negatively-charged anions (see the ionic liquids article in the previous issue). They are ideal for combatting pollution because they cannot evaporate and pollute the atmosphere, and also because they can be tailor-made to suit a wide variety of applications, including mercury capture.

Working closely together, QUILL and PETRONAS designed a new ionic liquid-containing material, now called Hycapure-Hg™, which can capture all species of mercury from 'raw' natural gas without any of the problems associated with older technologies. In less than four years, this material moved from first experiments in the laboratory on the gram scale to an industrial scale application on the ton scale, which has been producing clean gas continuously, in two mercury removal units, since November 2011 (see photos on next page).

The transformation of Hycapure-Hg™ technology from (a) laboratory scale, to (b) 100 g pilot plant scale, and to (c) 15 ton industrial scale

It normally takes about seven to ten years to get a process commercialised in the oil and gas industry. The speed at which our new process was deployed reflects both the simplicity of the process and the enthusiasm of PETRONAS to implement this green technology. Also, compared to other technologies for mercury removal from natural gas, our process absorbs mercury faster and more efficiently, and is also much safer and more economical to use. PETRONAS have recently made our new technology available for use worldwide in a business deal with a speciality chemical company, Clariant, which will make and sell Hycapure-Hg™. The consequence of this is that, globally, release of mercury into the environment from natural gas processing should reduce significantly.

An award-winning collaboration

"EVERYBODY has won, and all must have prizes." – The Dodo

The success of the PETRONAS/QUILL collaboration in developing our mercury removal technology has been recognised in the multiple awards it has won. These accolades include five Institute of Chemical Engineering (IChemE) awards in 2013 and 2014 – in the Institute's awards history, no other entry has achieved this before. We also won the Royal Society of Chemistry's 2014 'Teamwork in Innovation Award'. It is hoped that these accolades will increase the public awareness of the benefits of ionic liquids in general, and herald the way for more exciting developments in the near future.

Dr Maggel Deetlefs is CEO of QUILL and Prof Ken Seddon is Co-Director. QUILL is the Queen's University Ionic Liquid Laboratories in Belfast, Northern Ireland: quill.qub.ac.uk

Look here!

The previous Catalyst article by the same authors about ionic liquids:

http://www.catalyststudent.org.uk/cs/article/378

Mercury as art: Alexander Calder's mercury fountain at the Fundació Joan Miró in Barcelona. See it in operation: https://www.youtube.com/watch?v=Kv3XbKH3-lQ