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NOTE: Image sources…
1. https://www.harwellcampus.com/history/
2. https://www.ansto.gov.au/research/facilities/opal-multi-purpose-reactor

The future of medical radioisotope production in the UK - Part Two

This second article in a two-part series examines the historical and possible avenues of future production of medical isotopes in the UK. It follows an earlier article published in the July/August edition of Nuclear Future that introduced the topic of nuclear medicine.

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The UK has a significant history in the development and production of radioisotopes for the diagnosis and treatment of disease yet, over the years, production facilities have shut down without a suitable national-level production facility to replace them. The COVID-19 pandemic and Brexit have highlighted how vulnerable the UK's patient outcomes can be as the majority of medical isotopes we use are imported. However, there are studies and research being conducted to investigate avenues of future radioisotope production in the UK, including extracting them from existing waste and establishing a new research reactor.

Historical production

In the previous article we introduced the ideas of using radioisotopes to diagnose and treat various forms of disease. The most common of which is the short-lived metastable ^{99m}Tc that is currently used in over 80 % of diagnostic procedures. Only a few research reactors still operate worldwide for production of medical isotopes, including the ^{99}Mo parent of ^{99m}Tc, but many of these facilities are due to cease production within the next ten to twenty years.

Since the early age of nuclear power a variety of research reactors have been constructed in the UK for materials testing and radioisotope production. However, only a few of those research reactors produced isotopes for the diagnosis and treatment of disease. The first research reactors in the UK included the low-power air-cooled reactors, Graphite Low Energy Experimental Pile (GLEEP) and its successor British Experimental Pile 0 (BEPO), built at Harwell in the late 1940's. The two reactors produced medical isotopes including ^{131}I for the treatment of thyroid cancer and ^{32}P for ovarian cancer. When BEPO closed in 1968, the DIDO and PLUTO reactors on the same site took over radioisotope production until they also shut down in 1990. The 100 kW research reactor CONSORT, which was constructed at Imperial College London in 1963 and closed in 2012, also produced medical isotopes.

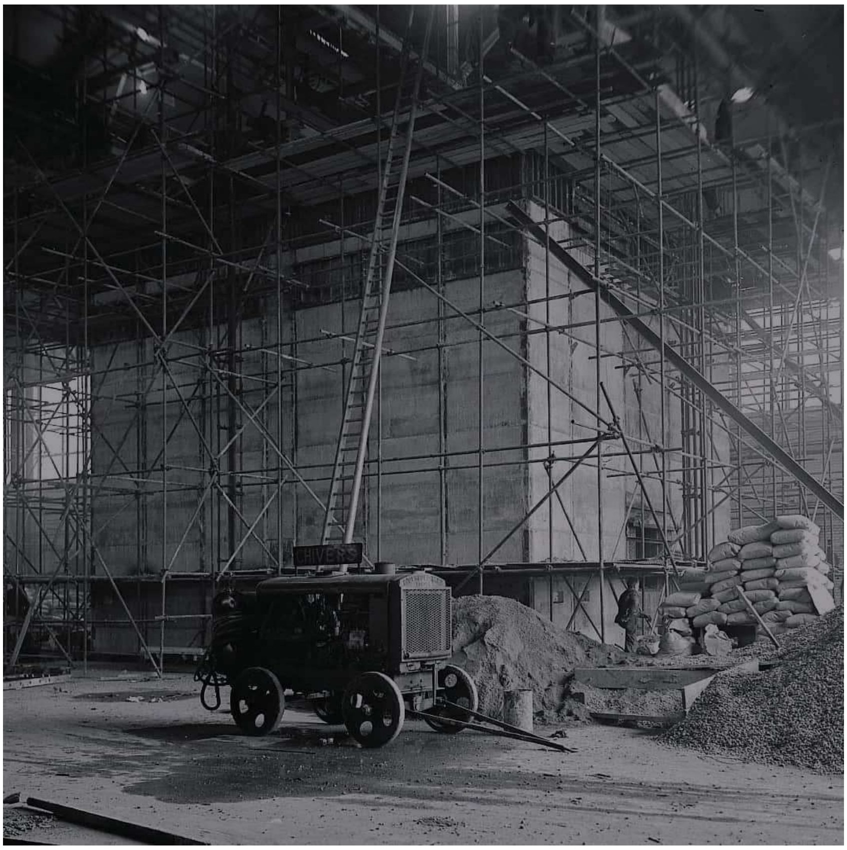

Figure 1: The construction of the Graphite Low Energy Experimental Pile (GLEEP) at Harwell that first reached criticality in 1947.

Current facilities

There is now no research reactor within the UK that is producing medical isotopes. There are alternative methods of production without the need of a research reactor (discussed in detail in part one of this article) and many have been adopted in the UK. During the second world war, Thorium Ltd. in Amersham produced luminescent painting from radium concentrate, which later led into the production of radium capsules for the treatment of cancer. From 1949 the renamed Radiochemical Centre (which later became Amersham International) processed and exported the isotopes produced both on-site and at Harwell. The production of medical isotopes was a significant contribution to the sales of the Centre e.g. in 1957, 50 % of the isotope exports were for medicine with the remainder shared between industrial purposes and research activities.

A number of cyclotrons were built across the country and there are now many, particularly smaller ones situated within hospitals, for isotope production or external beam therapy. The first that were built explicitly for the commercial production of medical isotopes were situated at The Radiochemical Centre in the 1960’s, but cyclotrons were used for fundamental research. The University of Birmingham has an established history with multiple accelerators, starting with the construction of the Nuffield Cyclotron in 1948. Whilst the cyclotron was initially used for nuclear physics investigations and general nuclide production, it was not until the 1980’s that the university began production of ^{81}Rb (i.e. ^{81m}Kr generators) for pulmonary ventilation imaging. The Nuffield Cyclotron closed in 1999 and the production of ^{81}Rb was passed to Hammersmith Hospital with their MC40 cyclotron. The University of Birmingham acquired a Scanditronix MC40 cyclotron in 2004 and re-established production of ^{81}Rb as the MC40 cyclotron at Hammersmith Hospital closed in 2006.

A recent development being investigated at Astral Neutronics and the University of Bristol in collaboration with Bangor University's Nuclear Futures Institute is the use of small fusor devices to produce medical isotopes. Fusors are compact machines that use nuclear fusion to generate protons or neutrons that can generate isotopes. A phone-booth sized piece of equipment could be sited in a hospital or research facility to produce made-to-order isotopes for use to treat and diagnose illnesses.

Brexit and the COVID-19 pandemic

Unfortunately, the scope and scale of medical isotope production is limited in these alternative routes and so over 80 % of the medical isotopes used within the UK are imported, mainly from EU sources. The combination of Brexit and the COVID-19 pandemic have had a complex effect on the provision of nuclear medicine services in the UK. With no UK based research reactors producing medical radioisotopes and the possibility of a no-deal Brexit, the UK created a stockpile of long-lived radioisotopes. This predominantly included isotopes used in therapy as most isotopes used in imaging, including ^{99}Mo for use in Single-Photon Emission Computed Tomography (SPECT), have a half-life too short for stockpiling. To attempt to ensure a supply of these short-lived radioisotopes air freight contracts were taken out as a contingency against long road transport delays. Early in the pandemic transport delays were also a concern with the cancellation of international flights threatening to interrupt ^{99}Mo shipments. Overall, during the first wave of the pandemic the UK saw a 65 % reduction in nuclear medicine services. This drop can be observed in Figure 2~~Figure 1~~, which shows the annual number of diagnostic images performed in England that are based on medical isotopes. The isotopes used in Positron Emission Tomography (PET) like ^{18}F can be produced in small hospital-based cyclotrons and so would not be affected as much. A significant drop is observed in 2021 for 'nuclear medicine' which includes both diagnostic and therapeutic isotopes. Whether this decline was caused by supply chain issues, staff shortages, increased safety precautions, heightened patient fears or a combination of all these factors is unclear.

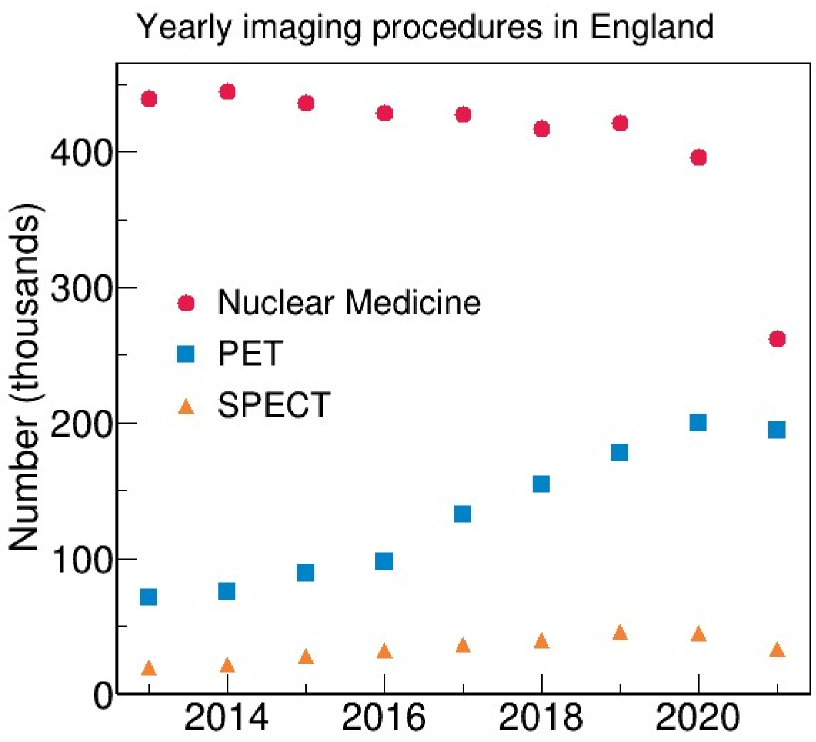

Figure 2: The annual number of diagnostic imaging procedures in England. The data is taken from the Diagnostic Imaging Dataset Statistical Release from NHS England.

Shortages have also occurred due to the unplanned maintenance and repairs of aging reactors, many of which are nearing the end of their useful life. The worst of these shortages occurred in 2007, and then again in 2009, when one of the largest suppliers of medical isotopes unexpectedly shutdown. When the National Research Universal (NRU) reactor in Canada experienced maintenance and water-leak issues, the remaining functional reactors were unable to compensate for the deficit resulting in a global shortage of several radioisotopes. Many hospitals did not receive ^{99m}Tc for weeks at a time, meaning scans were either cancelled or switched to older techniques with lower diagnostic quality and increased dose.

Potential future production

One of the most commonly used therapeutic medical isotopes is iodine-131, particularly for the treatment of thyroid cancer and hyperthyroidism. According to Cancer Research UK (CRUK), the five-year survival rate for both men and women is lower in the UK than the European average. It is expected that, as research reactors cease production of medical isotopes and supply issues become a concern, survival rates would be negatively affected. Under this context, there is growing interest in securing a national production of diagnostic and therapeutic isotopes. For example, the Welsh Government recently sponsored an optioneering study (conducted by Rolls-Royce) to examine how the UK could ensure a sustainable and secure supply of medical isotopes. They examined the various technologies available and concluded that the Open-Pool Australian Light water research reactor (OPAL) would meet the UK's demand while using low-enriched fuel and potentially run at a profit.

The time between construction and first criticality at OPAL was also less than five years. Using a points-based system, Trawsfynydd in North Wales was identified to be one of the best sites for such a facility as it has an existing license, and is not owned by the Ministry of Defence (i.e. there are no security issues with access). In addition, the Trawsfynydd site has an area of 15.4 hectares and only 0.72 hectares would be required for an OPAL style facility, while transit times between the site and all major UK hospitals would be within acceptable limits for the transportation of short-lived medical isotopes. However, the idea of establishing a facility at Trawsfynydd is still very much in its infancy.

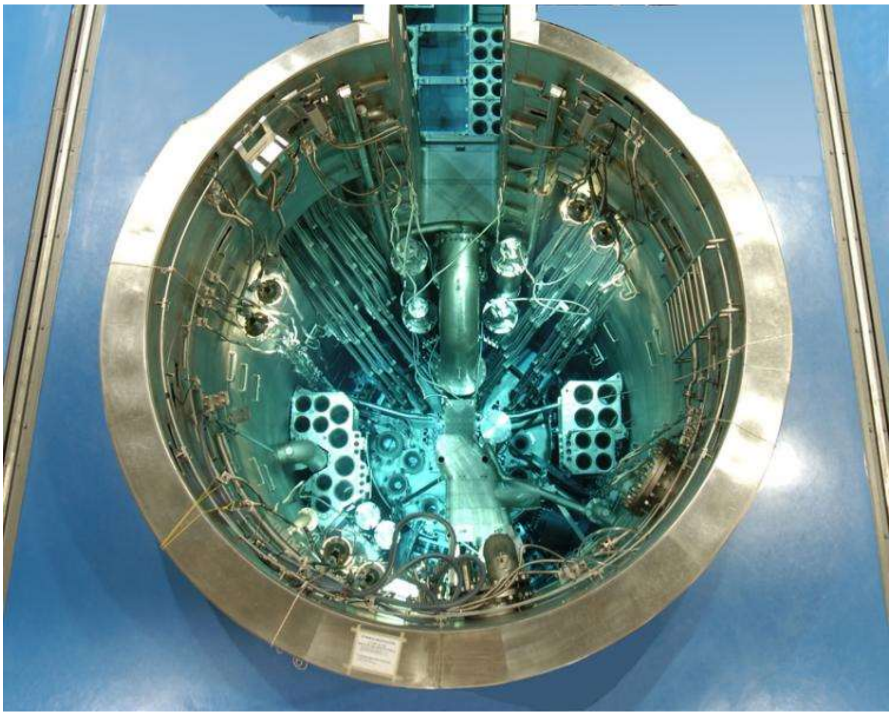

Figure 3:The Open-Pool Australian Light water research reactor (OPAL) in Australia.

Extraction from waste

The National Nuclear Laboratory (NNL) is also leading in another potential avenue for future production of medical isotopes, by reclaiming those of interest from nuclear waste. The UK's nuclear waste caches contain a mix of many radioisotopes, including those with current or emerging uses in nuclear medicine. By processing this waste useful isotopes could be removed and purified to a standard for medical use. This would form a supply of varied radioisotopes for both treatment of patients and medical research. The nuclear waste available in the UK falls into two categories, historic and under production. There is a set amount of historic waste available and once any useful radioisotopes have been extracted the supply will be exhausted. This is not suitable for the long-term treatment of patients, but could be useful for research purposes, particularly for radioisotopes where there is currently limited or no production. Waste which is still under production at nuclear sites offers a reliable supply of UK radioisotopes. Though limited by what is available in the waste, producing radioisotopes in this method has the benefit of using an existing resource without out the need to create more active material.

The UK has a rich history in developing and producing medical isotopes for the diagnostic and therapeutic treatment of disease, but over the years such facilities have closed down without sufficient national replacements. The UK now imports a significant proportion of medical isotopes from the EU, but such facilities are nearing closure and recent events have highlighted how vulnerable the supply of these isotopes can be and thus how easily patient outcomes can be affected. It is vital to investigate and support potential avenues of future production, including the construction of a research reactor or extracting isotopes from waste, so that the nation is not left behind.