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Technology Benefits Associated with Accelerator Production of Tritium

Gregory J. Van Tuyl

Los Alamos National Laboratory

Introduction

The Accelerator Production of Tritium (APT) offers a clean, safe, and reliable means of producing the tritium needed to maintain our nuclear deterrent (Ref. 1). Tritium decays away naturally at a rate of about 5.5% per year; therefore, the tritium reservoirs in nuclear weapons must be periodically replenished. In recent years this has been accomplished by recycling tritium from weapons being retired from the stockpile. Although this strategy has served well since the last U.S. tritium production reactor was shut down in 1988, a new tritium production capability will be required within ten years. Important technology benefits will result from direct utilization of some of the APT proton beam; others could result from advances in the technologies of particle accelerators and high power spallation targets.

Producing Neutrons and Tritium Using Accelerators

Particle accelerators use electromagnetic fields to accelerate charged particles, such as protons, to high energies (Ref. 2). Once the proton has sufficient energy, it can penetrate the nucleus of an atom and interact with the resident protons and neutrons. In some cases, the proton may slam directly into a neutron and dislodge it from the



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nucleus. More frequently, it simply deposits energy in the nucleus, leaving it in an excited state, resulting in a subsequent relaxation step called "evaporation." This results in some neutrons being emitted from the excited nucleus. By the time a high-energy proton interacts with a few atoms, giving off all its energy, dozens of neutrons may have been emitted. This process is called spallation, and the transformed atoms are called spallation products. Any material could be chosen as a target for the protons, but heavier materials, such as tungsten and lead, tend to provide more neutrons per unit of proton energy (Ref. 3). The nuclear transformation used in APT to make tritium is via capture of those neutrons in helium-3, which quickly emits a proton and becomes tritium.

Producing Isotopes

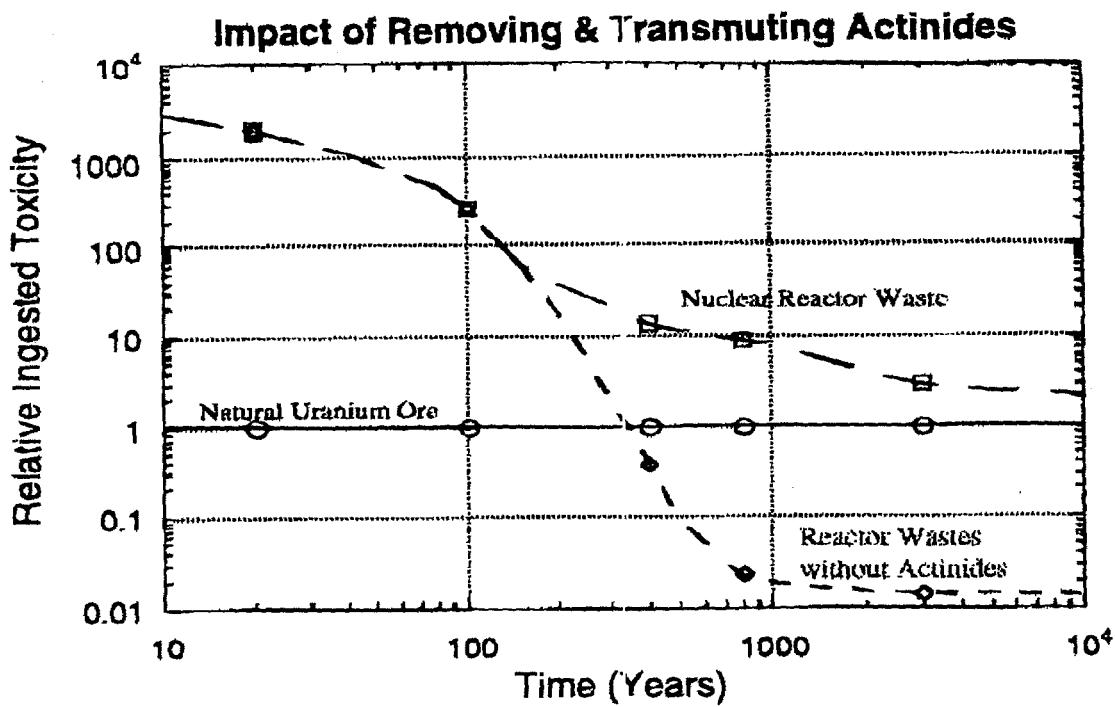
Of the dozens of medical isotopes in use or testing, several are produced using reactors—via either neutron capture or the harvesting of fission products. Many other isotopes are produced using accelerators, most commonly via direct capture of protons. APT represents a hybrid option, as it has characteristics of both accelerators (protons to be captured or trigger spallation) and reactors (neutrons from spallation). Further, if one inserts small targets of thorium or uranium, a small amount of fission could be induced to produce and harvest fission products. This creates one machine with the potential of producing most isotopes, with a "full" range of options for producing nuclear transformations.

The medical isotope market is currently dominated by a handful of tested and approved isotopes and medical procedures. However, there are many new procedures

undergoing pre-clinical studies and clinical trials, and many of these rely on the so-called "designer isotopes." The APT capability for producing such isotopes is unprecedented, with its full range of capabilities for nuclear transformations. Further, because the quantity required is modest, APT production of most such isotopes would have an almost imperceptible impact on tritium production.

Transforming Nuclear Wastes

The spent reactor fuel from nuclear power plants contains isotopes hazardous for millions of years. Because it is nearly impossible to engineer containers that will last more than a few centuries, most nations with nuclear power programs are struggling to develop waste repositories that will provide isolation for the requisite "geologic" time frame. Fortunately, it is only 1 to 2% of the spent fuel that poses the hazard. Further, there is the potential for using nuclear transformations to convert nearly all of the long-term hazards to materials that are either stable and harmless, or something that will be so within a few years. This has the potential of removing the "geologic" from waste repository, since the need for long-term isolation will be greatly diminished.



By transmuting long-lived isotopes, ATW can ease requirements for long-term isolation of nuclear wastes (Ref. 4)

Accelerator Transmutation of Waste (ATW) has the potential to fission the waste plutonium and higher actinides, and to convert long-lived fission products via neutron capture (Ref. 5). The ATW can safely fission the plutonium and higher actinides without blending in uranium. (In contrast, the uranium content needed for reactor stability would lead to the creation of additional plutonium and higher actinide wastes). In fissioning these wastes, ATW would produce electric power equivalent to about 17% of the current output of all U.S. nuclear power plants. A proton beam approximately 20% of APT beam could be used to drive a large ATW plant. If 10 to 20% of the APT beam capacity could be spared, ATW technology could be demonstrated at the APT site at Savannah River.

Additional Applications

Accelerator-driven particle beams have long been used to probe matter. Thousands of small accelerators currently produce electrons or photons used for imaging patients. A new imaging process called proton radiography, using high-energy protons, is under development to assure the safety and viability of aging nuclear weapons. Neutrons are excellent material probes, and accelerators have long been used to drive spallation neutron sources. The pulsed nature of many accelerators allows researchers to use event-timing techniques impossible with continuous streams of neutrons.

While we use accelerators to perform nuclear transformations, other concurrent transformations can help answer some of the fundamental questions of forefront science. For example, the APT will be a source of neutrinos several hundred times more intense than any comparable source on earth. On the other end of the scale, our understanding of how materials change when they are irradiated is largely determined through experience. Scientists in the fusion community have long wanted a source of neutrons like that found in the APT target to simulate a fusion reactor environment.

Summary

The APT may save thousands of lives through the production of medical isotopes, and it may contribute to solving the nation's problem in disposing of long-lived nuclear wastes.

But the most significant benefit may come from advancing the technology, so that the great potential of accelerator applications can be realized during our lifetimes.

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