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ENERGY MEASUREMENTS IN OXYGEN-INDUCED REACTIONS AT 60 A GeV AND 200 A GeV

WA80 Collaboration

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USE OF A UNITED STATES MID-PACIFIC ISLAND TERRITORY FOR A PACIFIC ISLAND REPOSITORY SYSTEM (PIRS)

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Abstract

The concept of using a mid-ocean island for a geologic high-level waste repository was investigated. The technical advantages include geographical isolation and near-infinite ocean dilution as a backup to repository geological waste isolation. The institutional advantages are reduced siting problems and the potential of creating an international waste repository. Establishment of international waste repository would allow cost sharing, aid U.S. nonproliferation goals, and assure proper disposal of spent fuel from developing countries. The major uncertainties in this concept are rock conditions at waste disposal depths and costs.

Introduction

A successful program for the disposal of high level wastes and spent fuel must be both technologically sound and institutionally acceptable. Current U.S. waste programs are based on construction of a continental geologic repository located within a state of the United States. There have been institutional difficulties in selecting a site for the repository; hence, it is desirable to consider alternatives. If alternative waste systems are to be considered, they should be based on solid technical and new institutional options to provide an independent backup to current programs. This paper describes one such option: an international geologic repository for the disposal of radioactive waste to be constructed beneath a mid-Pacific island territory of the United States, i.e, a Pacific Island Repository System (PIRS).

Island Selection, Island Characteristics, and PIRS Description

The basic technical concept is to build an international mined geologic repository for high-level waste and spent fuel beneath a mid-ocean island. The criteria for island selection are that it: (1) be geologically stable, (2) have appropriate rock formations for waste disposal, (3) be a territory of the United States, (4) be located in mid-ocean, (5) be isolated, and (6) have no indigenous population. Possible island candidates include Midway, Howland, Palmyra, Jarvis, Baker, Wake, Kingman and Johnston (Table I). Midway, Wake and Johnston islands have military bases; the others are uninhabited, primarily because they have no fresh water supplies. [a]

An island repository would be located in solid volcanic rock, 300 to 1500 m underground. All of the candidate islands are volcanically formed islands similar to Hawaii and were originally much larger. Ocean wave action cut the mountains down to below sea level, creating flat-topped mountains as viewed from the ocean floor. Simultaneously, the islands slowly sank into the ocean. As the islands sank, coral grew creating the typical coral atolls of this region. This geologic history

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[a] There are several hundred islands owned by France, Great Britain, Australia and the United States that may meet the above criteria for a repository. Because of historical factors, all U.S. territories are located in the mid-Pacific ocean. This paper addresses only U.S. options.

Table I

PIRS CANDIDATE ISLANDS

Island	Land Area (km^2)	Location
Midway	5.3	28° N: 179° W
Wake	5.5	19.25° N: 167° E
Johnston	2.5	17° N: 168° W
Palmyra	4.1	6° N: 162.2° W
Kingman Reef		6.27° N: 162.24° W
Howland	2.4	1° N: 176° W
Baker	1.5	1° N: 176 W
Jarvis	4.3	23° S: 160.02° W

(TABLE)

has created the following island stratigraphy: (1) a top layer of coral, (2) a layer of clay deposited from erosion of the mountains and degradation of the basalt, (3) layers of cracked volcanic rock resulting from the rapid cooling and environmental weathering, and (4) a core of solid volcanic rock. The core was formed as volcanic rock, was reheated, compressed by the mountain above and/or altered by seawater to produce high-integrity rock. It is this solid core which would be used for the repository. Depending upon the particular island chosen, the clay cap may also provide a major barrier to water and radionuclide migration. This clay layer is usually too thin to be used for waste disposal. The required geologic conditions are expected to be found only on the older mid-Pacific islands. The same lengthy geologic history implies only small land areas above sea level and little fresh water. Such conditions also result in small or nonexistent indigenous populations for these islands.

A typical Pacific atoll is 10 to 30 km in diameter, with 100 to 1000 km^2 of area in <50 m of water; in most cases, the area above sea level is only 2 to 5 km^2. The repository would be built beneath the island and its nearby ocean seabed. There are precedents for such construction in the numerous mining operations in Great Britain, Canada, and Japan that tunnel under the sea. The space limitation of an island repository is in the area above ground, not underground.

An island repository site has two engineering constraints that must be considered (1) the small land area above sea level and (2) the necessity to create all support facilities on the island including a seaport, an airport, a power plant, and housing. These constraints suggest that island operations should be limited to mine development, placement of waste packages underground, and backfilling of the repository. Any operation or repository function that can be done in the continental United States or elsewhere should be done there for both economic and logistical reasons. This could be accomplished by (1) creating a Treatment, Aging, Packaging and Shipment (TAPS) facility in the continental United States and (2) using totally self-shielded waste disposal packages. The TAPS facility would receive all spent fuel and high-level waste from the waste generators, treat the waste (if required), store and age radioactive wastes until the decay heat is sufficiently low to allow the use of large waste disposal packages, package the waste into sealed, externally clean, self-shielded waste disposal packages, and transport the packages to the island repository. The self-shielded waste disposal package, similar to those being developed in Switzerland and West Germany (1,2), would incorporate sufficient shielding to be safely handled manually. With this type of packaging, the island repository would have no need for remote handling operations, hot cells, or other specialized facilities for handling radioactive materials.

The major design parameters for one type of island repostiory system are summarized in Table II. This system is based on use of the West German design of self-shielded disposal container and waste transport by ships similar to those currently in operation shipping spent fuel from Japan to Europe (3).

Table II

ENGINEERING CHARACTERISTICS
OF A
PACIFIC ISLAND REPOSITORY SYSTEM

Spent Fuel	
Type	LWR
Age (yrs.) from reactor discharge	30
Decay heat (KW/MTIHM)	
for 20,000 MWD/MTIHM	0.4
for 40,000 MWD/MTIHM	0.85
Waste Package	
Type	Self-shielded
Design	West German
Capacity (MTIHM)	
Unconsolidated	1.6
Consolidated	5.3
Gross Wt. (MT)	52.1
Length (m)	6.1
Diameter (m)	1.34
Ocean Transportation[a]	
Ship Class	Pacific Pintail
Capacity (100-MT. Casks)	24
Assumed spent fuel/package (MTIHM)	5
Nominal Deadweight (MT)	2724
Draught, (m)	6
Length, (m)	103.9
Breadth, (m)	16.5
Capacity (MTIHM/year)	2160

[a]Based on existing Pacific Nuclear Transport Limited Ships used to move spent fuel from Japan to Europe for reprocessing. If shipped from western ports to Midway, two such ships would be required for all United States wastes. If TAPS were located in the eastern United States, shipment may be via eastern or Gulf Coast ports to the Pacific via the Panama Canel.

(Table1)

Environmental Rationale

There are potential environmental and licensing advantages in the use of an island repository. While all current repository proposals are designed to meet safety and environmental standards, it may be easier to demonstrate that required standards will be met and to obtain public acceptance for an island repository.

An island repository can provide substantial assurance that no adverse health effects would result from the buried radioa^tive waste. The PIRS concept provides two basic safety mechanisms: wastes are disposed of with high assurance of containment via multiple engineered and geologic barriers (as in a continental repository), but if there should be any unplanned long-term leakage of residual radioactivity from the repository, the hazard is minimized by dilution in the ocean.

In an island repository, the wastes would remain isolated from the biosphere inside the geologic formation until the radioactivity decayed to the levels found in natural rock. The confidence that geologic burial is workable is based on the recognition that natural ore deposits of arsenic, lead, and other toxic materials seldom poison people because most such deposits are geologically isolated from man in deep underground formations. The toxicity of these natural ore deposits is equivalent to that of a waste repository.

An additional safety factor would be the protective mechanism of greatly diluting any unplanned excape of radionuclides by the surrounding sea water. This environmental protection mechanism (which is unique to ocean-based disposal concepts) is based on a recognition that radioactive waste toxicity is small compared to the natural radioactive toxicity of the ocean, very little of the natural or manmade radioactivitiy in the ocean reaches man via any pathway and oceanic dilution would reduce the dose to biologically insignificant levels (4).

The advantages of ocean dilution as an additional, totally independent barrier for a repository [b] have been explicitly recognized by recent U.S. National Academy of Science studies on waste disposal (5), as well as by equivalent British investigations (6). Despite the obvious advantages, an island repository has not been seriously considered by the scientific community in the past because previous studies have concentrated on continental geologic disposal.

The well-known history and predictable future evolution of the existing Pacific islands greatly simplifies the required demonstration of long-term geologic repository performance and minimizes the uncertainties in long-term estimates of repository performance . The mid-Pacific islands constitute one of the most stable and predictable geologic settings on the planet (8). The risk of additional volcanic activity or other violent geologic events is so low as to be insignificant for some of these islands. Scientific evidence has shown that the Pacific islands were created by volcanoes over "hot spots" in the earth's crust and that as the Pacific tectonic plate moved, chains of islands were created by each hot spot. For example, Midway Island is at

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[b] Ultimately, the oceans are the final sink for any waste mankind generates since groundwater and rivers flow to the sea. Island sites do, however, avoid the possibility of creating high concentrations of toxic materials and avoid the most productive biological river and nearshore marine environments.

the end of the Hawaiian island chain, 1500 miles and millions of years away from the hot spot which created it. Along the chain from the island of Hawaii to the island of Midway, each subsequent island is older, has sunk further into the ocean, and has volcanoes which have been extinct longer. These trends continue beyond Midway in the Emperor seamounds (undersea mountains).

Island repositories would eliminate concerns about any accidental human intrusion into a repository in the future via water wells or other routes. There is little possibility for human intrusion on these islands because, as previously discussed, they are small, have no indigenous population, have limited or no fresh water, and most likely do not contain extractable resources. A concerted technological effort would be required to drill to a repository depth on a mid-Pacific island.

Finally, an island repository would provide better isolation from the consequences of such extreme, but unlikely, events as meteorite strikes or deliberate attack with very large nuclear weapons. These mid-ocean sites are separated from human population centers, as well as from each other, by hundreds of miles. An accident or an attack affecting such an island repository would have little impact on the continental United States or on the rest of the world because of this extreme geographic isolation.

Institutional Rationale

There are potential international and domestic institutional issues involved in establishing an island repository. Although the site would be located on U.S. national territory, disposal activities on our mid-Pacific islands would likely attract international attention and bring about both potential problems and opportunities. Because of the location, and because these islands are territories rather than states, a mid-ocean island repository might be used as an international waste repository for all nations. Such an option would provide major benefits for the United States. First, such actions would increase international support for such a facility. Many other nations also have repository siting problems and would likely support a U. S. owned international repository. Second, repository development costs could be shared with foreign countries resulting in potentially significant savings to U.S. utilities. Third, the United States could accept foreign spent fuel as part of its national nonproliferation policy. Last, the U.S. could have high assurance that wastes from less developed countries are properly disposed of. In nuclear affairs, accidents or problems in any one country have major impacts on nuclear programs everywhere. Thus, U.S. has a major incentive to see that wastes are properly managed.

Fewer domestic institutional issues would be associated with island repositories than with repositories located in the 50 states. These islands are U.S. Federal Territories, not parts of states such as Hawaii or California. This greatly simplifies state-federal relations since only waste transport and the TAPS facility would become state-federal issues. The repository would be strictly under federal control. The islands of interest have no indigenous populations. Only temporary military, defense contract, and communications company personnel are currently stationed on these islands. Islands such as Howland, Palmyra, and Midway are separated by hundreds of miles of ocean from the nearest populated islands and by even greater distances from major civilian populations. The isolation of these islands would not only have the significant safety advantages mentioned but should also greatly lessen the impact of the Not-In-My-Back-Yard (NIMBY) syndrome, since there are no neighbors for hundreds of miles.

Economic/Technical/Scientific Uncertainties

Whether the PIRS concept would be more or less expensive than other alternatives if used exclusively for wastes generated in the United States is unclear. The costs of a repository system are, in large part, determined by institutional factors rather than by the expense of the physical facilities. Shipping waste packages to the mid-Pacific would increase the transportation costs, and an island repository would have higher construction costs. On the other hand, if it becomes easier to license and obtain acceptance for an island repository, the savings from a shorter schedule could significantly reduce the total system expenses. Also, the possibility of creating an international repository, with international funding, would result in major cost reductions through the sharing of the repository development and operating costs.

There is strong evidence for the engineering feasibility of an island repository. World War II military history has proven that large, complex operations can be conducted from small islands. Similarily, the Alaskan pipeline construction experience has shown that complex operations can be conducted in remote, hostile climates. In addition, a series of studies was conducted in the 1970s on the feasibility of constructing a licensed, international, surface-located spent-fuel storage facility on these same islands as part of a program to reduce the potential for nuclear weapons proliferation (9). Although the program was not implemented, the studies indicated the technical feasibility of building licensed nuclear facilities on these islands.

The key scientific issue for an island waste repository, as for any other repositories, is the condition of the rock in which the wastes are to be emplaced. There is currently insufficient information to predict with confidence rock conditions at repository depth. The very characterisitics which make the PIRS attractive - isolation, old island geologic stability, no population, no water and no resources - also imply that there have been few incentives to study the local geology and hence limited information. This information can only be obtained by seismic surveys, construction of wells and shafts, and examination of the rock. It would be also highly desirable to investigate several islands simultaneously because of the possiblity that "island-specific" problems might be found. Based on the known geologic history, it is expected that acceptable rock is available under any mid-Pacific island. The greatest uncertainty is whether the acceptable rock is at an economically mineable depth for waste disposal.

The information currently available on the Pacific islands is primarily the result of a study in the 1960s to investigate their formation and geologic history. At Midway (10,11) the core drilling program made two boreholes that showed layers of coral, sedimentary rock, and a basement of basalt. The first borehole was drilled to a depth of 173 m (568 ft.) and basalt was found at the 157-m (516-ft) level. In the second borehole, 5 km from the first, the drilling went to a 504-m (1654-ft) depth, and basalt was found at 384 m (1261 ft). Seismic surveys indicated a strong discontinuity at approximate 600 m (2000 ft). This is thought to indicate a relatively monolithic basalt below this depth. If a repository were built on Midway, its depth would likely be between 700 and 1500 m. Recently the Defense Nuclear Agency, the U.S. Geological Survey, and the DOE have initiated, as part of certain defense programs, additional geological studies of the Enewetak and Johnston atolls. Because of its political status and population, Enewetak would not be considered as a repository site. These studies, which are expected to be published soon, will not only increase our knowledge of Pacific atoll geology but will have created a cadre of knowledgeable geologists in this area.

While there is a lack of information on old Pacific island marine basalt, drill holes have been placed into the marine basalts of the Pacific seabed as part of the Deep Sea Drilling Project (12, 13). The existing data indicate that rock permeability decreases by four orders of magnitude within <1000 m of depth. This, and other experimental evidence, suggests that tight, impermeable rock may exist below the first few hundred meters of older marine basalt and should also exist under the mid-ocean Pacific islands.

Summary

A central Pacific island repository in old basalt has potentially major technical/environmental advantages: waste isolation via geologic disposal with the independent safety backup of ocean dilution of any unplanned radionuclide leakage, a predictable area geologic history and predictable geologic future evolution, little risk of accidental future human intrusion, and extreme geographic isolation. There are also major institutional advantages, such as the possiblity of international cost sharing, support of United States nonproliferation goals and avoidance of the numerous and difficult Not-In-My-Back-Yard (NIMBY) state/federal problems. The geologic requirements for repository island selection (age and stability) fortuitously favor the selection of islands with the fewest institutional problems (no water and no people). The primary technical uncertainty of this concept is the condition of the rock at repository depth. The second uncertainity is cost.

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