CONF-850242--2

AN OCEAN DISPOSAL OPTION FOR BULK WASTES CONTAINING NATURALLY OCCURRING RADIONUCLIDES: AN ASSESSMENT CASE HISTORY

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DE85 004020

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ABSTRACT

There are 180,000 m^3 of slightly contaminated radioactive wastes (36 pCi/g radium-226) currently stored at the U.S. Department of Energy's Niagara Falls Storage Site (NFSS), near Lewiston, New York. These wastes resulted from the cleanup of soils that were contaminated above the guidelines for unrestricted use of property. An alternative to long-term management of these wastes on land is dispersal in the ocean. A scenario for ocean disposal is presented for excavation, transport, and emplacement of these wastes in an ocean disposal site. The potential fate of the wastes and impacts on the ocean environment are analyzed, and uncertainties in the development of two worst-case scenarios for dispersion and pathway analyses are discussed. Based on analysis of a worst-case pathway back to man, the incremental dose from ingesting fish containing naturally occurring radionuclides from ocean disposal of the NFSS wastes is insignificant. Ocean disposal of this type of waste appears to be a technically promising alternative to the long-term maintenance costs and eventual loss of containment associated with management in a near-surface land burial facility.

INTRODUCTION

The U.S. Department of Energy's (DOE) Niagara Falls Storage Site (NFSS) is located near Lewiston, New York, about 30 km north of Buffalo. Two types of materials contaminated with naturally occurring radionuclides are currently stored there: (1) about 11,000 m^3 of residues from processing of high-grade uranium oreas, and (2) about 180,000 m^3 of wastes--primarily soils that were contaminated by wind and water erosion of stored residues. The residues have an average radium-226 concentration of 67,000 pCi/g, whereas the wastes have an average concentration of 36 pCi/g (U.S. Dept. Energy 1984). Although both the wastes and residues will be consolidated within the containment system at Lewiston upon completion of interim remedial actions in

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1986, the U.S. Department of Energy must now decide how to manage these materials for the long term.

Public opinion in the Lewiston area is strongly in favor of removing both the wastes and residues to another site. However, removal of all these materials to another DOE site would require long-distance transport, would be very costly, and would preempt space that might be used for management of other hazardous material (U.S. Dept. Energy 1984). A combination alternative was therefore devised wherein the residues could be removed to another DOE site but the large volume of slightly contaminated wastes could either be left at the Lewiston site or removed to the ocean for disposal. Ocean disposal is a common bulk-waste disposal practice in the Northeast, historically used for large-volume materials such as sewage sludges, industrial wastes, dredged materials, and cellar dirt.

Removal of the waste from NFSS for either ocean disposal or long-term management at another land site would require many of the same excavation and long-distance transportation activities. The wastes would have to be excavated, loaded on dump trucks, and transported to either a land burial site or to a harbor for transfer to barges and transport to an ocean disposal site. After this point, the processes that would control risk of potential human exposure to the contaminated materials would be quite different.

OCEAN DISPOSAL SITE

The closest port supporting deepwater ocean disposal activities is the Port of New York and New Jersey (Figure 1). A number of old and active ocean disposal sites exist in this area, some nearshore in the apex of the New York Bight; others, such as Site 106, farther out to sea beyond the edge of the continental shelf. Site 106 is a deepwater dumpsite that has been extensively studied for the disposal of liquid industrial wastes. The existing environmental and disposal monitoring data, as well as the characteristics of Site 106, suggested that such a site would be an appropriate model for analysis of NFSS waste disposal. Currently, Site 106 is not designated for disposal of solid bulk wastes.

Site 106 is 204 km southeast of the entrance of New York Harbor (Figure 1). Water depths range from 1,440 to 2,750 m. The site and the area surrounding it have been used for the disposal of industrial wastes, sewage sludge, digester wastes, and munitions wastes. From 1951-1956 and 1959-1961, containerized low-level radioactive wastes with an inventory of 41,400 Ci were dumped south of the site (U.S. Environ. Prot. Agency 1980). Common pollutants in the industrial wastes dumped at Site 106 were cadmium, chromium, copper, lead, mercury, nickel, and zinc.

Site 106 lies in an area of considerable hydrodynamic complexity, between continental shelf waters and the Gulf Stream farther offshore. Sharp transitions between water masses, called fronts, are common; and, like atmospheric fronts, oceanic fronts are active areas of turbulence and convergence. Meanders in the Gulf Stream pinch off and

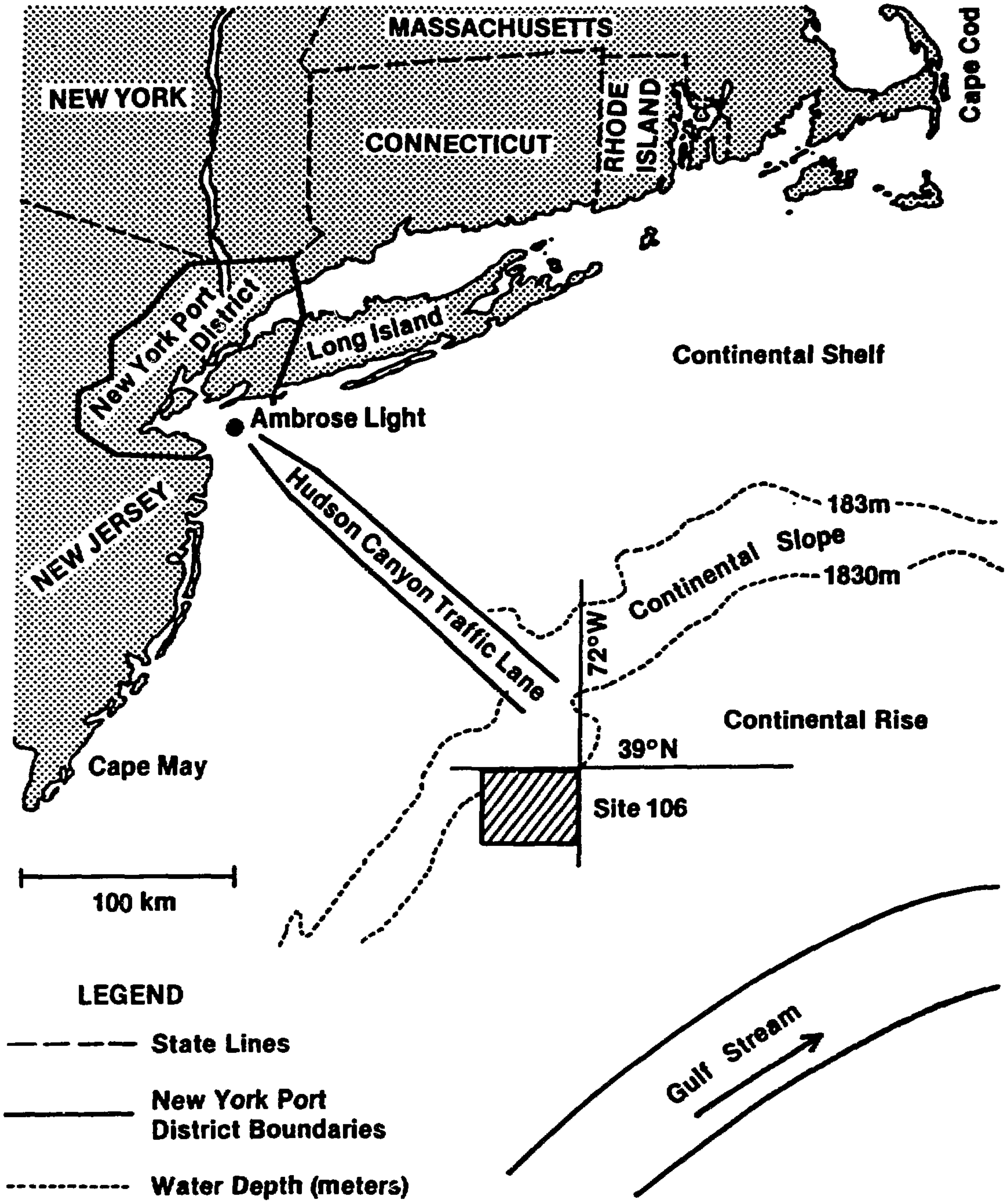

Figure 1. Location of Site 106 for Possible Ocean Disposal of the NFSS Wastes. Source: U.S. Department of Energy (1984).

become large swirling water masses that travel slowly to the southwest through the site (Bisagni and Kester 1981). These features create great variability in patterns of waste dispersion. Analyses of current velocities at Site 106 and at similar areas of the continental slope indicate that average currents are fastest in the upper waters and decline with depth. Flow is generally to the southwest, paralleling the bottom countours (Warsh 1975; Hamilton 1982). Average bottom current velocities are 3-4 cm/s, but various kinds of waves and internal oscillations may occasionally produce bottom currents on the order of 20 cm/s--fast enough to suspend fine-grained sediments.

OCEAN DISPOSAL SCENARIO

If ocean disposal of the NFSS wastes was chosen, a candidate disposal location would be selected by DOE and a permit for ocean dumping would be requested from the U.S. Environmental Protection Agency (EPA), which administers the Ocean Dumping Regulations (40 CFR 227). The permit would require site designation by EPA. Currently, it is unclear how the wastes would be classified for the purpose of ocean disposal. The regulations state that "radioactive materials" must be containerized before disposal and that the container must remain intact for as long as the wastes are harmful. However, the NFSS wastes are classified as nonradioactive for transportation purposes and, pending the outcome of proposed changes in both international and U.S. regulations, the wastes may be classified such that bulk disposal would be allowed (U.S. Dept. Energy 1984). If an ocean dumping permit application were filed, any ruling on waste classification would set a precedent for any similar proposals.

To transport NFSS wastes to a dock for loading onto barges, 61 truckloads of wastes would be shipped each day for a 6-month season in each of two years (Table 1). Dock operations would have to continue in two shifts. Three bottom-dump barges with a capacity of 4,100 metric tons would be required to keep up with the delivery of wastes. Barge trips would be scheduled every 4 days, weather permitting, from May through October.

WASTE FATE SCENARIOS

The NFSS wastes would be towed to the dumpsite and spilled from the open hull of a barge while under way. The behavior of the wastes after being dumped would depend on the physical composition of the wastes and on the prevailing oceanic conditions. The NFSS wastes contain 37% clays, 26% silts, and 37% sands (U.S. Dept. Energy 1984). The clays make the soils sticky or cloddy, particularly since they have been excavated and recompacted several times. We believe that because the forces that determine the mechanical properties of soil are very strong, the physical condition of the soil would be the overriding factor in determining the fate of the wastes after they were released into the ocean.

Table 1. Summary of Conceptual Design for Ocean Disposal of the NFSS Wastes

FACILITIES	DESCRIPTION
Disposal site	Site 106, 196 km (106 mi) SE of New York Harbor
Berthing	Dock in Port of New York, constructed of bulkhead with earth fill
Barges	Three, bottom-dump type, each with a capacity of 2600 m^3 (3400 yd^3)
Tug	Ocean-going for barge tow
Waste handling	2 crawler cranes with 1.5-m^3 (2-yd^3) clamshell buckets
Waste receiving	Waste bin, 350-m^3 (450-yd^3) capacity
Truck cleanup	Decontamination pad, water-treatment facility
Utilities services	Water, electricity
ACTIONS	**DESCRIPTION**
Waste delivery	61 trucks delivering 690 m^3 (920 yd^3) per day
Barge loading	120 m^3 (150 yd^3) per hour by clamshell bucket
Barge trips	3-5 per month (1-2 barges per tow)
Duration between barge trips	2.5 to 6 days
Round trip time to site	44 hours at 9 km/h (5 knots)
Dumping action time	Less than 30 minutes

Source: U.S. Department of Energy (1984).

Although waste dispersion has been well studied and monitored at Site 106, the results are applicable only to liquid wastes or non-cohesive slurries. No method is currently available to directly calculate the breakup of the soils into constituent particles upon contact with seawater. Therefore, the dispersion of the wastes at the dumpsite due to hydrodynamic conditions cannot be quantitatively predicted. In order to estimate the radiological risk from ocean disposal of the wastes, we found it necessary to define two waste fate scenarios that place bounds on the range of expected waste behavior (Figure 2).

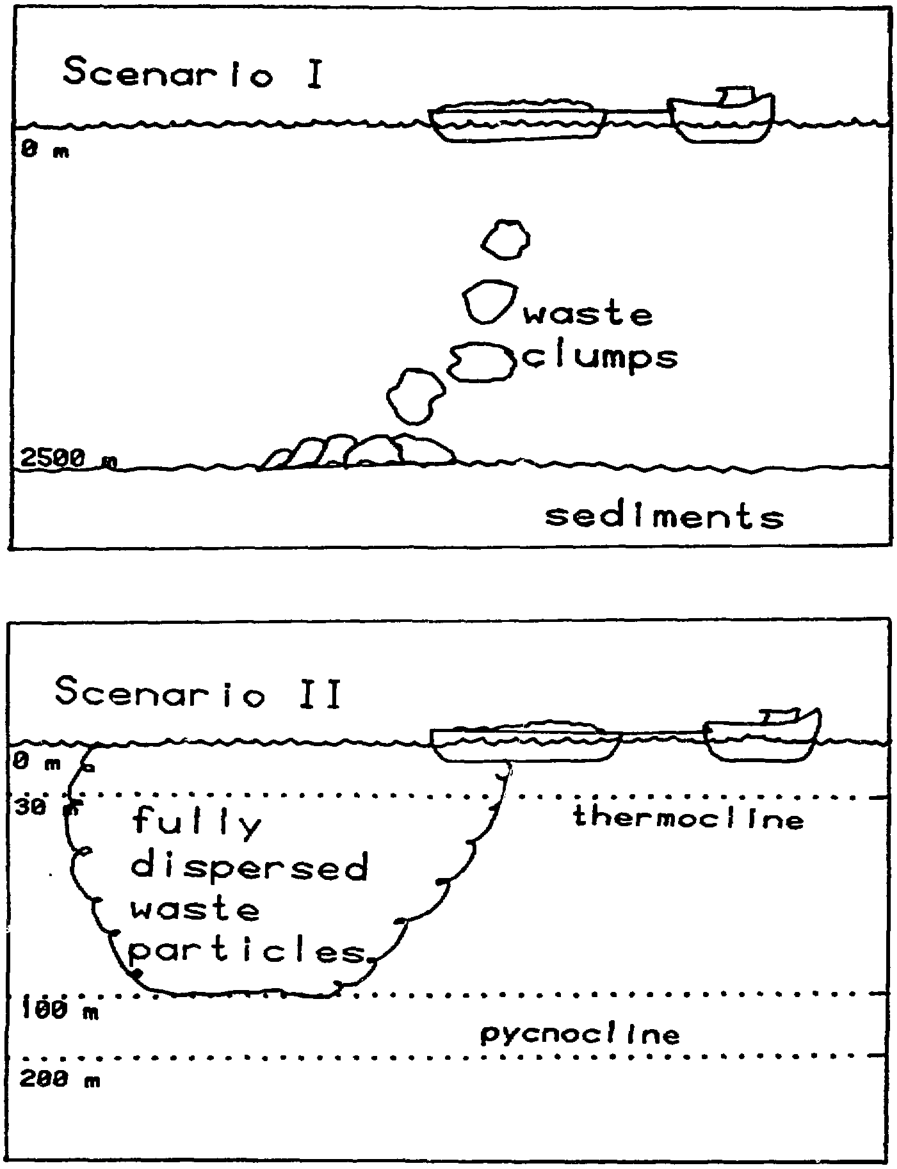

Figure 2. Schematic Diagram of Two Bounding Scenarios Used for Assessment of Impacts from Ocean Disposal of the NFSS Wastes. Source: U.S. Department of Energy (1984).

Scenario I: Complete Deposition on the Bottom of the Dumpsite

The clay content of the NFSS wastes gives the soil clumps cohesiveness. Thus, it is possible that little of the wastes would be dispersed in the surface waters of the dumpsite. For Scenario I, it is assumed that all the wastes are rapidly transported by gravity to the bottom sediments of the dumpsite. It is not possible to directly calculate how rapidly soil clumps would sink, because there is no information as to their size, shape, or roughness. These characteristics cause large departures from the particle-settling velocities predicted by the Stokes' equation (Graf 1971). The largest particle for which the Stokes' equation is applicable (0.2 mm) would sink to the bottom of the dumpsite in 38 hours. Other models that incorporate nonspherical shape and larger particle size (Graf 1971) suggest particles could arrive at the bottom of the dumpsite as soon as 0.8 hours after the dump. During a 0.8- to 36-hour descent time, the waste mass would be deposited 0.3 to 1.6 km from the dump location due to lateral transport by currents under average site conditions. It is unlikely that wastes from repeated dumps would all deposit in the same spot because of variability in dump location and ambient current speed and direction. If all the wastes were spread in contiguous areas, deep enough (7 cm) to minimize mixing with original sediments due to the action of burrowing animals, the wastes would cover 2.6 km of the ocean bottom (U.S. Dept. Energy 1984).

Trace elements in the wastes, including radium-226, would enter water in the pores of the sediments. From there, the trace elements would migrate into the overlaying water. The concentration of radium-226 picked up by water moving over the pile would be determined from the flux of the radionuclide from the pile, the dimensions of the pile, and the rate of water movement over the pile. At a current velocity of 3 cm/s, a 1-meter-thick layer of water would traverse a waste pile in 12 hours. If radium-226 leaves the sediments at the greatest flux calculated for this radionuclide (0.1 pCi/cm/yr) (Cochran 1979), then the concentration of radium-226 in the bottom waters would be increased by 0.002 pCi/L. The average natural seawater concentration of radium-226 is 0.1 pCi/L (Joseph et al. 1971).

Because commercial fishing is not practiced at the dumpsite, fish living directly on the waste piles are unlikely to be consumed by humans. However, juveniles of the grey sole might migrate from the dumpsite to an area of the continental shelf where they could be caught as adults. Because grey sole juveniles in the dumpsite area constitute only a very small portion of the total population of this mobile and widely distributed species, it is unlikely that any person would ever purchase more than one fish that had lived in the dumpsite. This fish could contain 0.0002 pCi of radium-226 per gram of tissue due to the wastes and 0.0016 pCi/g due to average background radium concentrations (U.S. Dept. Energy 1984).

Scenario II: Complete Mixing of Wastes in Seawater

Turbulence at the sea surface and in the barge wake may be strong enough to dissociate some of the soil into its constituent particles.

The soil-water mixture would act like a heavy liquid and begin to sink due to gravitational forces. A simplified calculation based on the method of Baumgartner (1970) indicates that convective descent would carry the wastes to a depth of between 90 to 1,100 m, depending on the geometry of the descending waste cloud. Even if all the soil was to mix thoroughly with seawater at the instant of dumping, it is not clear whether the wastes would remain near the surface for longer than a day or rapidly sink to great depths. Because the density of clay particles is greater than that of seawater, the particles would continue to settle after the downward momentum of the waste cloud had ceased. Settling rates calculated by Stokes' equation for ambient oceanographic conditions result in settling rates of $\leqq 0.003$ cm/s for clay particles, 0.003 to 0.2 cm/s for silt particles, and 0.2 to 13 cm/s for fine-grained sand. At these rates, clays would remain suspended for years, silts for months, and sands for a few days.

Clays that remained suspended near the surface for long periods would be spread and diluted by oceanic dispersion mechanisms. Based on several formulations describing diffusion of wastes in plumes, the width of the waste patch after four days would be 0.64 to 1.6 km during low mixing conditions and 2 to 17 km under high mixing conditions. If all the wastes remained suspended (a highly unlikely circumstance), the average concentrations of wastes after four days would be 20-100 mg/L under low mixing conditions and 0.1 to 10 mg/L under high mixing conditions (U.S. Dept. Energy 1984).

Because Site 106 is located beyond the continental shelf and is not used for commercial fishing, there would be no routine human contact with the wastes until they had been well dispersed. However, highly mobile, large, open-water fish such as sharks, tuna, and swordfish might come in contact with the wastes and later be caught in another area by commercial fishermen. If so, a person might purchase and consume a fillet or steak (1-2 kg) of such a fish from a commercial dealer. Because waste-dumping episodes would be limited to a two-year period and because the dumpsite would constitute only a minute portion of the range and distribution of large pelagic fishes, it is unlikely that anyone would ever consume the flesh of more than one fish that had spent enough time in a waste cloud to concentrate a significant amount of radium-226. If a fish did become equilibrated with radium-226 in a waste cloud during the first 4 days after disposal, the radium-226 concentration of the flesh would be increased by 0.0007 pCi/g (U.S. Dept. Energy 1984). Thus, a fish that normally contains a radium-226 concentration of 0.0016 pCi/g would contain 0.0023 pCi/g. If an adult human consumed 2 kg of the fish, that individual would incur an incremental dose of 0.0072 mrem to the whole body and 0.084 mrem to the bone (U.S. Dept. Energy 1984).

SUMMARY AND CONCLUSIONS

The concentrations of radionuclides in human food would not be raised significantly above normal background concentrations in either of the two worst-case ocean-disposal scenarios. The risk of human exposure to radionuclides in wastes emplaced in the ocean would be very low, due to restricted pathways back to man. Inhalation of radon gas and consumption of radium-contaminated water would be unlikely routes of human exposure. Exposure from food could be controlled by selection of a disposal site where the fishing potential was limited. Thus, deepwater disposal of wastes having low concentrations of naturally occurring radionuclides appears to be an attractive alternative to land-based disposal.

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