Chapter 6

RECOMMENDATIONS

Post-fission radioactive waste is highly toxic for extremely long periods of time--at least thousands, perhaps hundreds of thousands, or even a million years. Large quantities of HL waste are being temporarily and imperfectly stored in tanks at plutonium production facilities, and large amounts of spent fuel are being discharged periodically from commercial power reactors into increasingly crowded storage pools.

Whether optimists or pessimists, as we look to the future, we share an expectation that national security and energy supply, and the complex of institutions supporting those vital imperatives, will surely result in the creation of rapidly growing volumes of radioactive waste in the United States. There is an understandable tendency to shrink from this grim reality. An optimist may deny there is a serious problem because time and money will provide technology for a variety of solutions. A pessimist may deny there is a solution because--sometime, somewhere--man-made or natural cataclysms will inevitably breach any technological containment, and toxic radioactive waste will then spill or seep into the biosphere.

The morality of the U.S. predicament is arguable. Our survival as a nation seems to rest heavily on our nuclear arsenal, and the survival and well-being of our own and other societies depend on adequate energy. But is it moral to produce any toxic material with a half-life of 24,000 years? And is it right to continue activities which generate radioactive waste when a safe method for permanent disposal has not been fully demonstrated?

When viewed in such apocalyptic terms, the radioactive waste problem tends to befuddle the mind, polarize the public, and stalemate the government. But if we view the problem not as one that must be solved once and for all, but rather as one (among many) that must be dealt with now and for the foreseeable future, a number of steps can be taken immediately to strengthen substantially our capacity to manage radioactive waste now and in the future.

The following specific recommendations concerning policy goals, organization, and implementation emerge from and are supported by the preceding chapters of this report. It is noteworthy that most of them are not especially sensitive to future scientific revelations, technological developments, or changes in attitudes within society. While some of the recommendations may appear to be quite far-reaching -- especially those regarding a new structure for radioactive waste management -- it is important to recall that they can be implemented in most instances with little, if any, impact--welcome or resisted--upon large vested interests. There is today no long-term management of radioactive waste, no comprehensive scheme for regulation of such waste, and no commercial reprocessing industry.

Thus we have an opportunity -- perhaps our last clear chance -- for institutional development.

Policy Goals

1. The technological criteria for U.S. radioactive waste policy should be clarified and the applicability of such criteria to various categories of waste should be established.

The overall technological criteria should be containment and isolation from the biosphere of all post-fission radioactive waste. These criteria would be applicable to all phases of radioactive waste management, including temporary storage, treatment, and transport, as well as permanent disposition. The application of such criteria to permanent disposition would mean that radioactive waste would be completely contained and fully isolated from the biosphere for sufficient time to provide reasonable assurance that no significant increase in natural background radiation levels (local or general) will result if and when release occurs.

The criteria of containment and isolation would be generally applicable to commercial waste, whether or not commercial reprocessing is introduced, and to military waste. The criteria would be rigorously applied to all HL waste, existing and future. They would also be applied presumptively to all future TRU waste, so that the safety of less stringent criteria must be demonstrated before they are adopted. A separate study should be made to provide a basis for determining the extent to which these criteria would be retroactively applied to existing TRU waste.

2. <u>Institutional criteria for U.S. radioactive waste policy should be developed and adopted</u>.

One important institutional criterion would be the existence of strong incentives for safe management of radioactive waste. Institutional arrangements should generate strong incentives for the organizations and persons involved to play their respective roles--whether in waste management operations, safety regulation, or research and development--with intelligence and dedication. To the maximum extent possible, the incentive for safe management should be derived from within the organization having operational responsibility, rather than be imposed from outside by government regulation or public criticism.

A second criterion would be institutional stability. This requires differentiation of the radioactive waste problem into functional tasks or areas of responsibility, and development of a system of checks and balances that will govern relations among those charged with different areas of responsibility. The radioactive waste problem should be differentiated into management, regulation, and research and development. Primary responsibility for each functional task should be assigned to a different organization. The Congress would prescribe and adjust relations between managers, regulators, and technology developers.

Institutional stability also requires sufficient jurisdiction to perform all the interdependent components of an assigned functional task. Inadequate scope or jurisdiction will prevent effective overall performance.

A third institutional criterion would be adaptability. Whatever the initial institutional arrangements may be, they should be capable of responding to rapid expansion in the dimensions and to changes in the character of the radioactive waste problem. Radioactive waste institutions should also be capable of adapting to profound changes in the social and political environment in which the problem is embedded.

3. <u>As part of developing policy for the long-term disposition of radioactive waste, the choice between permanent disposal and perpetual care should be fully assessed and debated</u>. Current policy favors permanent geologic disposal with some reasonable possibility for short-term reversibility. An alternative policy would be reliance on technological systems requiring virtually perpetual surveillance

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and some degree of active management. The safety of reliance on human care rests on a prediction that the stock of knowledge concerning nuclear matters will continue to develop and accumulate and never be substantially lost throughout the future turbulent course of human history.

Permanent geologic disposal involves present commitments based on present knowledge and predictions of the geologic history of particular formations hundreds of thousands of years into the future. Once made, geologic dispositions will be extremely difficult, if not impossible, for future generations to reverse if we guess wrong. Permanent geologic disposal thus relinquishes to nature the future management of radioactive waste.

Perpetual human care involves commitments that future generations can modify, including a basic shift from continued surveillance to permanent geologic disposal. As long as technological containment systems function safely, surveillance alone is required. However, there is no technological artifact in existence today, or that can reasonably be expected to appear in the future, that is capable of performing its originally intended function for hundreds of thousands of years. Deterioration in performance is unavoidable. Therefore, perpetual human care entails periodic renewal and replacement of waste containment systems in addition to the surveillance that will always be necessary. Perpetual care retains for man the waste management burden and imposes that burden on successive generations.

Technological systems, which maintain retrievability, and geologic disposal methods, which do not, may both be vulnerable to natural catastrophes. However, technological systems may be more vulnerable than geologic disposal to man-made calamities.

The motives which underlie a policy which favors permanent disposal of radioactive wastes are ambiguous indeed--confidence in our present mastery of nature, fear of future social collapse, or an expedient desire to elicit public acceptance of nuclear power development. Similarly, the motives underlying a policy favoring surveillance are difficult to discern--faith in the capacity of man to muddle through, fear of future natural disasters, or an expedient desire to do the minimum necessary to accelerate nuclear development.

Organization

4. <u>A national Radioactive Waste Authority should be established as a federally chartered public corporation. The Authority would manage all HL and TRU wastes under U.S. jurisdiction or control</u>.

The Authority would be independent of ERDA. It would be governed by a board of directors composed of members drawn from government, nuclear industry, the academic research community, and the general public.

The Authority would own all HL and TRU waste facilities, including facilities for temporary storage, treatment and permanent disposition of waste, and any specially constructed waste transport containers. It would take over existing commercial and military waste facilities. If commercial reprocessing is not authorized, the Authority would construct and manage central storage facilities for commercial spent fuel.

The Authority would be self-financing. It would issue bonds and recover the full costs by appropriate charges for waste management services to be paid by those receiving such services. It would be authorized to conduct waste management operations itself or to contract with private industry for the conduct of such operations.

The Radioactive Waste Authority would thus be intended to provide comprehensive, integrated, efficient management of both commercial and military HL and TRU wastes.

5. With NRC as the primary agency, a comprehensive regulatory framework should be established to assure the safety of all radioactive waste management operations under U.S. jurisdiction or control. A unified regulatory framework is necessary whether or not the national Radioactive Waste Authority recommended above is established. The regulatory framework would be specified by federal law that would preempt all other regulation.

All radioactive waste management operations involving HL or TRU waste, including both commercial and military waste at existing and future facilities, would be subject to the same regulatory scheme. Of course, different kinds of waste from different programs would be regulated differently when circumstances warranted, but all regulation would occur within a single framework.

NRC would have authority to promulgate specific standards for all licenses, to license sites, to license the construction and operation of fixed facilities, to monitor all waste management activities, and to order appropriate corrective and enforcement measures. NRC would also have authority to license waste management demonstration projects, except for small pilot projects. DOT and NRC would have concurrent authority over all radioactive waste transport operations subject to U.S. jurisdiction or control.

Within the NRC-headed regulatory framework other interested federal agencies such as ERDA, EPA, and CEQ, affected state governments, and interested international agencies would have advisory roles in major waste management licensing actions. EPA would continue to have authority to develop generally applicable radiation protection standards which would guide NRC development of standards for radioactive waste licenses. Any waste storage or disposal option proposed to be implemented beyond U.S. national jurisdiction would be subject to concurrent U.S. regulatory jurisdiction and approval by the international commission described in recommendation 7.

6. <u>ERDA should continue to have primary government responsibility to conduct and sponsor research and development of radioactive waste management technologies</u>. ERDA would plan research and development priorities and programs in consultation with NRC, EPA, the U.S. nuclear industry, the proposed national Radioactive Waste Authority, and interested international agencies.

7. <u>The U.S. government should propose that an international Radioactive Waste Commission be established under the IAEA</u>.

Prior approval of the IAEA commission would be required for any storage or disposal operation which would result in the dispersal or emplacement of radioactive waste beyond national jurisdiction. This would include seabed, ice sheet and outer space disposal of HL waste and ocean dumping of TRU waste. Prior consultation with the IAEA commission would be required before each national licensing action authorizing a permanent waste disposition under exclusive national jurisdiction.

Implementation

Recommendations concerning specific waste management strategies and permanent disposition options are beyond the scope of this report. A recommendation is developed, however, with respect to the decisional process.

8. The pending NRC decisional process concerning commercial reprocessing and widescale use of mixed oxide fuel should be expanded to include the issues of radioactive waste partitioning, HL waste management, and spent fuel management in the event of no reprocessing.

The NRC decision is currently focused on the economic, environmental, health and safety, and safeguards issues arising out of commercial reprocessing, and plutonium-bearing fuel fabrication and recycling in light water reactors. Equivalent attention should be given to radioactive waste management issues. A decision to permit reprocessing includes irreversible commitments concerning the composition and future management of radioactive wastes. Since the schedule for NRC's reprocessing decisional process is slipping, it should be possible to include full discussion of commercial radioactive waste management issues based on ERDA's forthcoming environmental impact statement without undue additional delay. Indeed, failure to include radioactive waste management issues based on the fullest practicable weighing of risks, costs and benefits may make the NRC's decisional process vulnerable to legal attack for failure to comply with NEPA.

GLOSSARY

actinide series: The series of elements beginning with actinium, element No. 89, and continuing through lawrencium, element No. 103, which together occupy one position in the periodic table. The series includes uranium, element No. 92, and all the man-made transuranium elements. The group is also referred to as the "actinides."

cladding waste: Fuel rods in most nuclear reactors today are made up of fissionable materials clad in a protective alloy sheathing which is relatively resistant to radiation and the physical and chemical conditions that prevail in a reactor core. The spent fuel rods, after removal from the reactor and storage to permit radioactive decay of the short-lived fission products, are removed and in certain fuel cycle systems, are chopped up, and the residues of the fissionable materials are leached out chemically. The remaining residues, principally the now radioactivated cladding material (zirconium alloys, etc.) and insoluble residues of nuclear fuel, fission products, and transuranium nuclides, are left behind as cladding waste, which is a special category of transuranium radioactive waste.

critical: The condition in which a material is undergoing nuclear fission at a self-sustaining rate; the critical mass of a material is the amount that will self-sustain nuclear fission when placed in an optimum arrangement in its present form; the minimum critical mass is the amount of a fissile isotope that will self-sustain nuclear fission when placed in optimum conditions.

curie (Ci): A unit of radioactivity defined as the amount of a radioactive material that has an activity of 3.7×10^{10} disintegrations per second (d/s); millicurie (mCi) = 10^{-3} curie; microcurie (uCi) = 10^{-6}; nanocurie (nCi) = 10^{-9}; picocurie (pCi) = 10^{-12} curie; femtocurie (fCi) = 10^{-15} curie.

decommissioning: The process of removing a facility or area from operation and decontaminating and/or disposing of it or placing it in a condition of standby with appropriate controls and safeguards.

disposal: The planned release or placement of waste in a manner that precludes recovery.

engineered storage: The storage of radioactive wastes, usually within suitable sealed containers, in any of a variety of structures especially designed to protect them from water and weather, and to help keep them from leakage to the biosphere by accident or sabotage. They may also provide for extracting heat of radioactive decay from the waste.

fertile material: A material, not itself fissionable by thermal neutrons, which can be converted into a fissile material by irradiation in a reactor. There are two basic fertile materials, uranium-238 and thoruem-232. When these fertile materials capture neutrons, they are partially converted into fissile plutonium-239 and uranium-233, respectively.

fissile material: While sometimes used as a synonym for fissionable material, this term has also acquired a more restricted meaning, namely, any material fissionable by neutrons of all energies, including (and especially) thermal (slow) neutrons as well as fast neutrons; for example, uranium-235 and plutonium-239.

fission: The splitting of a heavy nucleus into two approximately equal parts (which are nuclei of lighter elements), accompanied by the release of a relatively large amount of energy and generally one or more neutrons. Fission can occur spontaneously, but usually is caused by nuclear absorption of gamma rays, neutrons or other particles.

fissionable material: Commonly used as a synonym for fissile material. The meaning of this term also has been extended to include material that can be fissioned by fast neutrons only, such as uranium-238. Used in reactor operations to mean fuel.

fission products: The nuclei (fission fragments) formed by the fission of heavy elements, plus the nuclides formed by the fission fragments' radioactive decay.

fuel (nuclear, reactor): Fissionable material used as the source of power when placed in a critical arrangement in a nuclear reactor.

fuel cycle: The complete series of steps involved in supplying fuel for nuclear power reactors. It includes mining, refining, the original fabrication of fuel elements, their use in a reactor, chemical processing to recover the fissionable material remaining in the spent fuel, re-enrichment of the fuel material, and refabrication into new fuel elements, transportation of materials between these various stages, and management of radioactive waste.

fuel reprocessing: Processing of irradiated (spent) nuclear reactor fuel to recover useful materials as separate products, usually separation into plutonium, uranium, and fission products.

half-life: The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years. After a period of time equal to 10 half-lives, the radioactivity of a radionuclide has decreased to 0.1 percent of its original level.

high-level liquid waste: The aqueous waste resulting from the operation of the first-cycle extraction system, or equivalent concentrated wastes from subsequent extraction cycles, or equivalent wastes from a process not using solvent extraction, in a facility for processing irradiated reactor fuels. This is the legal definition used by ERDA; another definition used at the ERDA Hanford Reservation for its waste, is: fluid materials, disposed of by storage in underground tanks which are contaminated by greater than 100 microcuries/milliliter of mixed fission products or more than 2 microcuries/milliliter of cesium-137, strontium-90, or long-lived alpha emitters.

ionizing radiation: Any radiation displacing electrons from atoms or molecules, thereby producing ions. Examples: alpha, beta, gamma radiation, short-wave ultraviolet light. Ionizing radiation may produce severe skin or tissue damage.

isotope: One of two or more atoms with the same atomic number (the same chemical element) but with different atomic weights. An equivalent statement is that the nuclei of isotopes have the same number of protons but different numbers of neutrons. Isotopes usually have very nearly the same chemical properties, but somewhat different physical properties.

long-lived isotope: A radioactive nuclide which decays at such a slow rate that a quantity of it will exist for an extended period; usually radionuclides whose half-life is greater than 3 years.

nuclide: A species of atom having a specific mass, atomic number, and nuclear energy state. These factors determine the other properties of the element, including its radioactivity.

partitioning: The process of separating liquid waste into two or more fractions. In this report, partitioning is used specifically with reference to the removal of certain radioisotopes from the waste in order to facilitate subsequent waste storage and disposal. "Isotope mining" is used to describe the fractionation of waste when radioisotopes are extracted and used in other applications.

plutonium: A heavy, radioactive, man-made, metallic element with atomic number 94. Its most important isotope is fissionable plutonium-239, produced by neutron irradiation of uranium-238. It is used for reactor fuel and in weapons.

rad (Acronym for radiation absorbed dose): The basic unit of absorbed dose of ionizing radiation. A dose of one rad means the absorption of 100 ergs of radiation energy per gram of absorbing material.

radiation: The emission and propagation of energy through matter or space by means of electromagnetic disturbances, which display both wave-like and particle-like behavior; in this context the "particles" are known as photons. Also, the energy so propagated. The term has been extended to include streams of fast-moving particles (alpha and beta particles, free neutrons, cosmic radiation, etc.). Nuclear radiation is that emitted from atomic nuclei in various nuclear reactions, including alpha, beta, and gamma radiation and neutrons.

radioactive contamination: Deposition of radioactive material in any place where it may harm persons, spoil experiments, or make products or equipment unsuitable or unsafe for some specific use. The presence of unwanted radioactive matter. Also radioactive material found on the walls of vessels in used-fuel processing plants, or radioactive material that has leaked into a reactor coolant. Often referred to only as contamination.

radioactivity: The spontaneous decay or disintegration of an unstable atomic nucleus, usually accompanied by the emission of ionizing radiation. Activity is a measure of the rate at which a material is emitting nuclear radiations, and is usually given in terms of the number of nuclear disintegrations occurring in a given quantity of material over a unit of time. The standard unit of activity is the curie (Ci), which is equal to 3.7×10^{10} disintegrations per second. The words "activity" and "radioactivity" are often used interchangeably.

radioisotope: A radioactive isotope. An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation. More than 1300 natural and artificial radioisotopes have been identified.

rem: A unit of measure for the dose of ionizing radiation that gives the same biological effect as one roentgen of x rays; one rem equals approximately one rad for X, gamma, or beta radiation.

roentgen (abbreviation r): A unit of exposure to ionizing radiation. It is that amount of gamma or X rays required to produce ions carrying 1 electrostatic unit of electrical charge (either positive or negative) in 1 cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen, German scientist who discovered X rays in 1895.

special nuclear material (SNM): Plutonium, uranium-233, uranium-235, or uranium enriched to a higher percentage than normal of the 233 or 235 isotopes.

transuranics: Nuclides having an atomic number greater than that of uranium (i.e., greater than 92). The principal transuranium radionuclides of concern in radioactive waste management are tabulated below with their half-lives:

Nuclide	Half-Life (Years)	Principal Decay Modes
Neptunium-237	2,140,000	alpha
Plutonium-238	86	alpha, spontaneous fission
-239	24,390	alpha, spontaneous fission
-240	6,580	alpha, spontaneous fission
-242	379,000	alpha
Americium-241	458	alpha
-243	7,950	alpha
Curium -245	9,300	alpha
-246	5,500	alpha, spontaneous fission

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The transuranium nuclide produced in largest amounts is Pu-239; Am-241 is also produced in significant amounts.

transuranic (TRU) waste: Any waste material measured or assumed to contain more than a specified concentration of transuranic elements. This is the definition used by ERDA. The specified concentration is currently set at 10 nanocuries of alpha emitters per gram of waste. (The Nuclear Regulatory Commission (NRC) has not yet adopted a regulatory definition of transuranic waste.) The 10 nanocurie/gm standard is under scrutiny and may be revised upward.

uranium: A radioactive element with the atomic number 92 and, as found in natural ores, an average atomic weight of approximately 238. The two principal natural isotopes are uranium-235 (0.7% of natural uranium), which is fissionable, and uranium-238 (99.3% of natural uranium), which is fertile. Natural uranium also includes a minute amount of uranium-234. Uranium is the basic raw material of nuclear energy.

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