Chapter 2

BACKGROUND

PURPOSE OF THE STUDY

No disposal facility is presently available for greater-than-Class-C (GTCC) low-level radioactive waste (LLW) and some waste generators claim to be running out of on-site storage capacity. Through the Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA), the Federal Government (i.e., the U.S. Department of Energy (DOE)) was made responsible for disposing of GTCC waste. In accordance with this legislation, DOE published a report in February 1987 entitled Recommendations for Management of Greater-Than-Class-C Low-Level Radioactive Waste. This report focused primarily on the types and quantities of GTCC waste and regulatory needs; there was little analysis of disposal options for this waste. DOE plans to select a disposal technology within the next several years after evaluating disposal alternatives.

Without knowing disposal requirements or when a disposal facility will be available, GTCC waste generators have difficulty estimating their storage needs and designing waste packages for both storage and disposal. Congress therefore asked **OTA to analyze different management options and to develop an integrated management approach for** GTCC waste. Before presenting this analysis, we provide some background information on GTCC waste and the factors that are most important in safely managing it. Finally, we present an analysis of different management options by comparing them to technologies that are or will be used to store and dispose of other types of radioactive waste.

Since concerns about managing GTCC waste have been raised only within the last few years,[1] very little information on this type of LLW has been published. DOE's February 1987 report, cited above, is the only report published on the subject. A few papers on GTCC waste have also been presented at conferences on radioactive waste management. Additional information used in this analysis was obtained from reports and papers that deal with all types of radioactive waste, letters and memos from Federal agencies, and communications with personnel working in this and other related areas of radioactive waste management.

WHAT IS GTCC LOW-LEVEL RADIOACTIVE WASTE?

Low-level radioactive waste is defined in the LLRWPAA of 1985 by what it is not, rather than by what it is. LLW includes radioactive waste not classified as spent fuel, high-level waste (HLW) from reprocessing spent fuel or uranium mill tailings. These types of radioactive waste are defined generally in Appendix A; special terms relating to radioactive waste are defined generally in Appendix B.

The NRC has developed a classification system for commercial LLW based on its relative danger to human health and safety. This system establishes three classes of LLW -- A, B, and C -- with Class C being generally the most radioactive and/or long-lived of these three classes. Tables and procedures for classifying LLW are provided in Title 10 of the Code of Federal

[1] GTCC waste has only existed since 1983 when the U.S. Nuclear Regulatory Commission's classification system was established (10 CFR 61).

Regulations Part 61 (10 CFR 61).[2] LLW that is more radioactive and/or long-lived than Class C is called greater-than-class C (GTCC) waste.

GTCC WASTE TYPES AND GENERATORS

GTCC waste comes from the full range of typical LLW generators including: nuclear utilities, hospitals, universities, and various industries (e.g., pharmaceutical manufacturers and radiography firms). The GTCC waste produced by these generators is briefly described below.

A

GTCC waste can be generated during reactor operations and during reactor dismantling, called decommissioning. Operational waste can include non-fuel reactor core components (e.g., control rods), neutron sources required for reactor start-up, fission chambers, and spent ion-exchange resins and sludges containing high levels of radioactivity from coolant and fuel pool cleanup activities. When nuclear power plants wear out or become uneconomical to operate, they will be refurbished or shut down and eventually decommissioned. Most GTCC waste from refurbishing and decommissioning will be activated metals, such as stainless steel core shrouds that separate the reactor core from the reactor vessel (Knecht, 1988 and NRC, 1984a).

B. Fuel Manufacture and Test Facilities

In the past, fuel fabrication facilities used plutonium in advanced fuel research and development. All of these facilities have either been decommissioned or are in the process of being decommissioned. Since the Federal Government frequently sponsors the activities at these facilities, most facility operators have contractual arrangements to transfer much of their GTCC wastes to DOE for storage and disposal (NRC, 1984a).

Three companies currently operate test facilities that sample and examine reactor fuels. The wastes from these facilities consist of solidified aqueous waste; activated metals in the form of contaminated equipment, cladding, and metal cuttings; and other solid wastes such as glassware and resins (Knecht, 1988). Much of these wastes contain enough transuranic radionuclides to exceed Class C limits and, therefore, would be classified as GTCC. In addition, some GTCC wastes are likely to contain hazardous chemicals (NRC, 1984a; DOE, 1987a).

C. GTCC Sealed Source Manufactures and Distributors

GTCC sealed sources are small radiation sources containing granules of radioactive material that are sealed inside capsules. Sealed sources are physically small; they range from 0.3 inches to 20 inches long. These sources are used in density and moisture gauges, well-logging equipment, radiography devices, X-ray fluorescence tubes, and static eliminators. For example, radiography firms check the integrity of pipe welds using instruments containing sealed sources. The activity of GTCC sealed sources can range from a few curies to several thousand curies. Common radionuclides used in GTCC sealed sources are americium-241, cesium- 137, strontium-90, plutonium-238, and plutonium-239 (Knecht, 1988 and NRC 1984a).[3]

Some GTCC sealed sources can be recycled by their original manufacturer, especially if the user is willing to purchase a replacement source. A whole sealed source that was of high-activity can sometimes be reused in an instrument requiring a lower-activity source, or the material inside a sealed source can sometimes be recycled by repackaging it in a new source.

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[2] See 47 Federal Register 248 (Dec. 27, 1982).

[3] Sealed sources can also contain radium-226 -- a radionuclide that is not regulated by the Federal Government.

Lower-activity sources are generally more difficult to recycle. The 40 or so manufacturers of sealed sources in this country are unlikely to accept obsolete sealed sources from their customers if recycling is uneconomical (DOE, 1987a).

Manufacturers of sealed sources often possess contaminated equipment resulting from processing sealed sources. This equipment, which can exceed Class C limits, is often bulky and difficult for manufacturers to store.[4]

D. GTCC Sealed Source Users

GTCC sealed sources are used by industries, universities, colleges, hospitals, and other medical institutions conducting research and development. For example, GTCC sealed sources are used both to diagnose and to treat certain diseases, such as cancer. A NRC or Agreement State license[s] is required to manufacture, distribute, possess, and use GTCC sealed sources, but individual sources are not licensed.

The NRC estimates that there may be 25,000 to 30,000 GTCC sealed sources now in use in the United States (NRC, 1988 b). Most of these sealed sources will be recycled rather than disposed. The NRC estimates that by the year 2020 there may be about 4,000 GTCC sealed sources being held for disposal by as many as 3,000 licensees (NRC, 1988b).[6]

E. Other Generators

Some companies use carbon-14 as a tracer in manufacturing specialty chemicals for biological and chemical research. Some waste from these processes is GTCC waste. GTCC waste can also result from decontaminating out-dated facilities from other commercial operations. Such clean-up activities can generate contaminated soil, trash, and ion-exchange resins.

GTCC WASTE VOLUMES AND RADIOACTIVITY

At the end of 1985, about 14,000 cubic feet of packaged GTCC waste had been generated; this waste is now in on-site storage.[7] For comparison, this volume is equivalent to about 6 tractor trailers. The present rate of GTCC waste production is about 1,400 cubic feet of packaged GTCC waste per year.[8] For comparison, about 1.8 million cubic feet of Class A, B, and CLLW was shipped for disposal to Barnwell, South Carolina; Richland, Washington; and Beatty, Nevada in 1987. This annual volume of A, B, and C waste is over 100 times greater than GTCC waste's annual volume.

By 2020, the total volume of packaged, untreated GTCC waste is projected to be about 170,000 cubic feet.[9] About 60 percent of this volume -- 105,000 cubic feet, which is equivalent to 40 tractor trailers -- is projected to be produced when nuclear power plants are

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[4] K. Amiauer, President of Isotope Products Laboratories (a small radioisotope producer in Burbank, California), personal communication, Sept. 1988.

[s] A State that wishes to regulate the radioactive material licensees in its state can apply to the NRC for Agreement State status. Such States have to demonstrate that their regulations are equivalent to or more restrictive than the NRC'S regulations. There are 29 States that have received Agreement State status.

About one-third are NRC licensees; about two-thirds are licensed by Agreement States.

[7] These are the most recent data on waste volumes from M. Knecht, EG&G (DOE contractor), personal communication, September 1988.

[8] M. Knecht, EG&G (DOE contractor), personal communication, September 1988.

[9] M. Knecht, EG&G (DOE contractor), personal communication, September 1988.

shut down and decommissioned or refurbished for use beyond their licensed operation period.[10] Reactor refurbishing will probably generate about the same amount of GTCC waste as decommissioning. The remaining 40 percent of the total volume -- about 65,000 cubic feet, which is equivalent to 25 tractor trailers -- will be generated by all activities other than the refurbishing or decommissioning of nuclear reactors.

According to DOE's 1987 GTCC report, decommissioning or refurbishing of reactors will begin around 2000 and increase significantly within the following decade (DOE, 1987a). For those reactors that are shut down, rather than refurbished, decommissioning may be delayed, perhaps until the middle of the 21st century (see Appendix C). Putting a reactor in storage for 30 to 50 years -- commonly referred to as SAFESTOR -- will significantly decrease both the volume and the radioactivity of LLW produced. GTCC waste generation, therefore, may peak around 2015, but the peak may not be as large as predicted by DOE (1987a). Furthermore, the GTCC waste volumes from decommissioning and/or refurbishing may be spread over a considerable period after 2015 (EPRI, 1987).

There is some uncertainty associated with GTCC waste volume projections. Due to packaging and treatment procedures, waste volumes can both increase and decrease. Waste generators, for example, could decide to melt down certain contaminated metals which would decrease voids in packaging containers and reduce volumes. Furthermore, some generators (e.g., utilities) may package a small volume of GTCC waste with very low-activity LLW, thus reducing the average activity of a package's volume to Class C, Class B, or even Class A limits. This technique greatly increases waste volumes, but may make it possible to generate very little GTCC waste during decommissioning or refurbishing of some nuclear power plants.

Given the expected long-term storage period, GTCC waste may need to be repackaged for further storage and/or disposal. Such repackaging may increase waste volumes significantly, but it is not clear. It is assumed in this report that packaging will generally increase waste volumes by about 7 for wastes generated by decommissioning or refurbishing nuclear power plants and by about 5 times for all other GTCC waste.

Even though the volume of GTCC waste that will be generated in the United States is small, its radioactivity is very high relative to other classes of LLW. By the end of 1985, the radioactivity of all GTCC waste in storage was about 4.5 million curies.11 For comparison, this is more than three times the radioactivity of all other commercial LLW that was disposed of by the end of 1985.

Much radioactivity in GTCC waste is contributed by cobalt-60 which has a 5.3 year half-life. Cobalt-60, by itself, is never GTCC because of its short half-life. When cobalt-60 is associated with enough longer-lived radionuclides, the waste has to be classified as GTCC. Cobalt-60 cannot normally be separated out of this waste. The overall radioactivity of GTCC waste containing significant quantities of cobalt-60 will decay substantially in about 50-60 years.

The cumulative radioactivity of all GTCC waste generated by 2020 is projected to rise to 80 million curies. Over 99 percent of this activity (and the heat output from the waste) will be produced by nuclear power plants.[12]

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[10] M. Knecht, EG&G Idaho, Inc. (DOE contractor), personal Communication, September 1988.
[11] M. Knecht, EG&G Idaho, Inc. (DOE contractor), personnal communication, September 1988.
[12] M. Knecht, EG&G (DOE contractor), personal communication, September 1988,,

RISKS ASSOCIATED WITH GTCC WASTE

To safely manage GTCC waste, it is essential to understand the risks associated with the waste. These risks can be significant because of the thousands **of potential** GTCC waste generators and the waste's high concentrations of radioactivity. In determining whether a particular type of radioactive waste will pose significant risks to humans and the environment, a variety of interrelated factors can be considered: the overall concentration of the radionuclides per unit of waste relative to their concentration in the environment, the half-lives of the radionuclides in the waste, the types of radiation emitted, the heat generated by the waste, and potential pathways to human exposure.

Exposure pathways can be short-term or long-term; each affects humans differently. There is a great deal of uncertainty about the biological damage caused by a particular exposure to radiation, especially from long-term, low-level exposures (National Research Council, 1980). Short-term exposure of workers can occur during waste generation, processing, transportation, or disposal. Short-term exposure of the public can occur if there is an accident during any one of these management stages. Long-term exposure of the public can occur if there is any release and off-site migration of radionuclides from buried radioactive waste by ground water to a drinking water source. Inadvertent intruders of a disposal site could also suffer from short- or long-term exposure.

The NRC weighed all the interrelated factors mentioned above in establishing three classes of LLW (A, B, and C). Because of the different risks posed by various radionuclides, each of the three classes of LLW has different concentration limits for different radionuclides. Generally speaking, if the concentrations of radionuclides in a commercial generator's waste exceed the limits listed in Table 1 and the waste is not spent fuel, the waste is considered GTCC.[13] If waste contains alpha-emitting transuranic radionuclides that have half-lives exceeding 5 years and are in concentrations exceeding 100 nanocuries per gram, the waste is also considered GTCC.[14] There are no defined upper limits on the concentration of radionuclides for GTCC waste.

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13 If there are two or more radionuclides in a waste, the sum of fraction rule [10 CFR 61.55(a)(7)] must be used to determine the class of the waste.

14 Transuranic radionuclides with concentrations less than 100 nanocuries per gram are considered Class A or Class C LLW, depending on the radionuclide's concentration.

Table 1. Approximate Limits for Radionuclides in GTCC Waste

Radionuclide	Minimum Concentration (curies per cubic foot)	Half-Life (years)
Short-lived		
Strontium-90	200	30
Cesium-137	130	30
Nickel-63	20	100
Nickel-63 in activated metal	200	100
Long-lived		
Carbon-14	0.2	5,800
Carbon-14 in activated metal	2	5,800
Nickel-59 in activated metal	6	75,000
Niobium-94 in activated metal	0.006	20,000
Technetium-99	0.08	210,000
Iodine-129	0.002	16,000,000
Alpha emitting transuranic nuclides with half-life greater than 5 years	100 nanocuries per gram	
Plutonium-241	3,500 nanocuries per gram	
Curium-242	20,000 nanocuries per gram	

Source: Adapted from Tables 1 and 2 from 10 CFR 61.55

GTCC waste can be extremely dangerous, even lethal, if not handled properly. Although low radiation doses usually produce few if any short-term effects, the following examples illustrate the potential danger associated with higher radiation doses from radioactive material.

(1) In 1987, a sealed source -- the size of a paint can and containing 1400 curies of cesium-137 -- was stolen from a cancer therapy machine located in an abandoned clinic in Brazil. Within one month, four people had died and 54 others were hospitalized for varying lengths of time. People known to be contaminated were shunned by their communities. Contaminated buildings, vehicles, and furniture had to be decontaminated or taken into custody (Anderson, 1987 and Roberts, 1987).

(2) In 1962, a boy living in Mexico found an abandoned, pencil-sized radiography gauge containing a highly radioactive, broken, sealed source. The boy played with the gauge and took it home. The boy's mother then found the gauge and placed it on the kitchen shelf for several more weeks. The boy died shortly thereafter and over the next few months three other members of his family also died (Marshall, 1984 and West, 1984).

(3) A California man unknowingly exposed himself to excessive levels of radiation in 1979 when he placed a 29-curie sealed source in his back pocket for about 45 minutes. An initial

reddening of the skin under the pocket eventually became an open wound about 4 inches in diameter and almost an inch deep. Despite two subsequent skin grafts, the wound had still not healed completely nineteen months after the accident. In a similar accident in the 1970s, both legs of an Argentine man had to be amputated after receiving excessive doses of radiation from a sealed source he had been carrying in his front pant's pocket (NRC, 1986a).

In this country, protective measures (listed in Table 2), required to prevent such exposure to radioactive material over the short- and long-term are established by the EPA, NRC, and the U.S. Department of Transportation (DOT) in the form of standards, regulations, and guidance. Short-term risks are addressed through standards and regulations for worker exposure, packaging, storage, and transportation. For example, it is estimated that about 60 to 75 percent of all GTCC waste emits levels of radiation that warrant remote rather than contact handling by workers (Knecht, 1988).

Long-term risks are addressed through EPA standards and NRC disposal facility regulations that address environmental considerations, waste stability, and facility design. Table 2 lists some of these protective measures. Due to the magnitude and longevity of the risks associated with most GTCC waste, near-surface disposal used for Class A, B, and C LLW is generally not acceptable for GTCC waste.[15]

[15] 10 CFR 61.55(@(4)(iv)

Table 2. Qualitative Description of Protective Measures
for Managing Low-Level Radioactive Waste

Against short-term risk prior to disposal	Against long-term risks after disposal
1. Worker regulations and standards - limited exposure - film badges for measuring exposure	1. Environmental considerations: - minimize water infiltration (ground water depth & flow, amount of rainfall) - geologic stability
2. Packaging regulations - labels - protective shielding if needed	2. Waste stability & facility design - packaging requirements - barriers to environment (e.g., depth of disposal, an intruder barrier, and a stable cap on the facility) - environmental monitoring program - buffer zone
3. Storage guidelines	
4. Transportation regulations and standards - packaging design (e.g.,labeling and stability and shielding if needed) - manifest forms for tracking waste packages - trucking and train transport regulations and standards (e.g., for routing and driver training)	3. Institutional control factors (e.g., fences, signs, and a site closure plan) - Government ownership of sites

Sources: Adapted from:
10 CRF 20 (Standards for Protection Against Radiation)
10 CFR 61 (Licensing Requirements for Land Disposal of Radioactive Waste)
49 CFR 171,172,173,177 (Radioactive Materials; Routing and Driver Training Requirements)

To evaluate the management of GTCC waste, as compared to other types of radioactive waste, two primary factors were used 1) the concentration of radioactivity in the waste, and 2) the length of time that the waste poses a significant risk to **humans, or the longevity** of risk. These two factors help policy makers to qualitatively understand the relationships between the various types of radioactive waste. Table 3 and Figure 1 are based on this analysis.

Table 3 illustrates that the average concentration of radioactivity in GTCC waste is closest to that of defense HLW and higher than any type of commercial radioactive waste except spent fuel. As of 1985, the average concentration of radioactivity in GTCC waste was 300 curies per cubic foot. If the activity from all short-lived radionuclides (e.g., cobalt-60) was ignored, this concentration would drop to about 50 curies per cubic foot. By 2020, GTCC waste's average concentration is projected to increase significantly to about 2500 curies per cubic foot. If all short-lived radionuclides were again ignored, this concentration would drop to about 1500 curies. This concentration of radioactivity will be much higher than it is today because by 2020 more than half of GTCC waste activity will be contributed by radionuclides (primarily nickel-63) with half-lives of 100 years or longer.

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16 M Knecht EG&G Idaho, Inc. (DOE contractor), personal communication, September 1988-

Table 3. Relative Risks from Different Types of Radioactive Waste

Waste type	Average Concentration [a] (Ci/tcublc foot) End of 1985	2020	Relative longevitv of risk
Spent fuel	200,000(1)	100,000(1)	Ten thousand years[b]
High-level waste (defense)	100(1)"	100(1)	Hundreds to few thousand years[b]
Transuranic waste (defense)	02(l)	~(l)	Few to several thousand years[c]
Greater-than-C1ass-C waste*	300(2)	2,500(2)	Hundreds to few thousand years[c]
Low-level waste			
Total commercial	01(0	01(1)	
class c	7 (l&9)		Few 100 to 500 years[d]
Class B	2 (l&3)		Few 100 years[d]
Class A	O J (w		Less than 100 years[d]

Much of the initial radioactivity associated with GTCC waste is due to short-lived radionuclides (e.g., cobalt-60). By 2020, more than half of its radioactivity will be contributed by long-lived radionuclides (e.g., nickel-63).

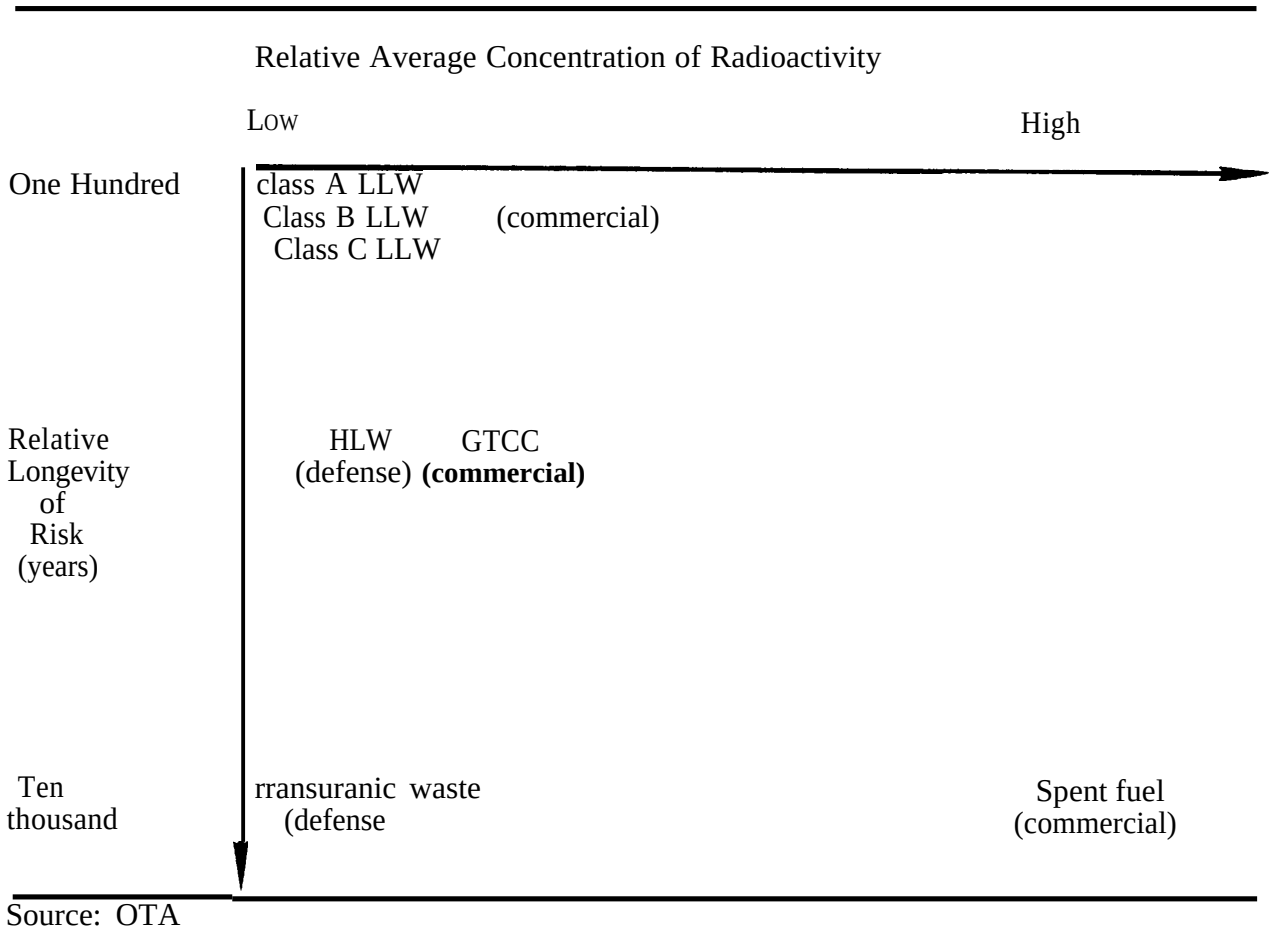
[a] **Average concentrations for waste in storage or shipped for** disposal.
[b] Semi-quantitative approximation of longevity of risk based on the half-life of the radionuclides in the waste, and EPA standards for radioactive waste disposal.
[c] Semi-quantitative approximation of longevity of risk based on the half-life of radionuclides in the waste relative to EPA standards for radioactive waste disposal.
[d] Semi-qualitative approximation of longevity of risk based on NRC 10 CFR 61 regulations for LLW.

Sources:

1) U.S. Department of Energy, Integrated Data Base for 1987: Spent Fuel and Radioactive Waste Inventories. Projections. and Characteristics, DOE/RW-0006, Rev. 3 (Washington, D. C.: September 1987).
2) Knecht, M., EG&G (DOE contractor), personal communication, September 1988.
3) U.S. Department of Energy, The 1986 State-bv-State Assessment of the Low-Level Radioactive Waste Received at Commercial Disposal Sites, National Low-Level Radioactive Waste Management Program, DOE/LLW 66T, December 1987.

Figure 1 shows a qualitative plot of Table 3. The average concentration of radioactivity is plotted against the average longevity of risk associated with different categories of radioactive **waste.** With regards to these two factors, GTCC waste shares characteristics that are most similar to defense HLW. One important difference between these two wastes is that much of GTCC waste activity will be from long-lived nickel-63, which is slow to migrate because it will be contained in activated metals, while defense HLW activity is from shorter-lived radionuclides (e.g., cesium- 137 and strontium-90), which are generally more mobile.

Figure 1. Qualitative Comparison of Relative Risks from Different Types of Radioactive Waste



Source: OTA

PRESENT PROBLEMS ASSOCIATED WITH GTCC WASTE MANAGEMENT

The DOE has deferred a decision about GTCC waste disposal pending further analysis of various disposal technologies. The NRC staff has published a proposed amendment to 10 CFR 61 that would require the disposal of GTCC waste in **a** deep-geologic repository, unless the DOE develops another licensable option (Federal Regisrer **May** 1988). The deep-geologic repository for commercial spent fuel and defense HLW will not be available, however, for fifteen to twenty years. If another disposal technology were chosen, it would require a similar length of time to develop a separate facility for GTCC waste disposal.

The major concern is the storage of this waste **until a disposal facility can be made available. Specifically, potential storage problems include: 1) the management of sealed sources, 2)** GTCC material users phasing out operations that use this material and needing off-site storage capacity, 3) the increasing number of GTCC waste generators that expect to exhaust their on-site storage capacity during this period, 4) the potential for waste packages to degrade during this period.

In its 1987 report on GTCC waste, DOE tentatively committed the Federal Government to accept GTCC waste within the next two years for storage at an as yet unspecified facility. Considering this time frame, this facility would presumably be an existing, DOE storage facility, all of which are unlicensed to ensure national security of defense operations. There is some question in Congress whether an unlicensed facility would be appropriate for commercial GTCC waste.

These problems and options for managing GTCC waste are discussed in the following section.