APPENDIX F
CHARACTERIZATION OF SOLID MATERIALS

Introduction

This appendix provides supporting information for Chapter 3 on the types of NRC licensed facilities and inventory estimates for materials released for each alternative.

Table F-1 lists commonly reported radionuclides for all licensees. For nuclear power plants, the radionuclide profile and relative fraction of each radionuclide are based on site characterization results and some low-level waste data. A single inventory was derived for all reactors, both operating and shutdown. The radioactivity profile assumed the presence of 17 radionuclides, as beta and gamma emitters, and transuranics. The most predominant radionuclides, comprising about 96% of expected residual radioactivity levels, are Mn-54, Co-58, Co-60, Ni-63, Fe-55, Cs-134, and Cs-137. For all other licensees, the listing is meant only to be illustrative of some of the most common radionuclides, while recognizing that radioactivity profiles in materials designated for release are expected to vary. It should be noted that the types and amounts of radioactive materials authorized under a license are not always reliable predictors of radionuclide distributions that might be found in potentially clearable material. The uncertainty about the presence of radionuclides and their relative fractions in any material is dependent on the license specifying types of radionuclides and their chemical and physical properties, processes or events leading to the release of materials, use of material control measures, and radioactive decay.

This Draft GEIS is focused on controlling the disposition of solid materials that are present in areas in NRC-licensed facilities where radioactive materials are used or stored. These areas are generally referred to as either restricted or impacted[1] areas. Despite its location in these restricted or impacted areas, much of this solid material has no, or very little, radioactivity resulting from licensed operations because (1) the material was not exposed to radiation, or (2) the material was exposed to radioactivity only minimally, or (3) it has been decontaminated. In this Draft GEIS, these solid materials are referred to as "potentially clearable" materials. These solid materials can include furniture and ventilation ducts in buildings; metal equipment and ferrous metals and copper pipes; wood, paper and glass; laboratory materials (gloves, beakers, etc); routine trash; site fences; concrete; soil; or other similar materials.

Other solid materials in these restricted or impacted areas can contain more appreciable levels of radioactivity. However, these are separated from those materials with no, or very small amounts of radioactivity at the licensed facility and are required to be disposed at licensed low-level waste (LLW) disposal sites under NRC's existing regulations in 10 CFR Part 61. Solid materials containing appreciable levels of radioactivity are not the subject of the Proposed Action. These materials are referred to as "activated" or "contaminated."

[1] A restricted area is defined in the NRC regulations at 10 CFR 20.1003 as an area to which access is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. An impacted area is defined in 10 CFR 50.2 as an area with some reasonable potential for residual radioactivity in excess of natural background or fallout levels.

Table F-1 Radionuclides Expected in Potentially Clearable Materials

Radiouclide	Power Reactors & ISFSIs	Research Reactors	Fuel Cycle Facilities & U-Mills	All Material Licensees	Complex Sites
H-3	x	x		x	
C-14	x	x		x	
P-32, P-33				x	
S-35				x	
Mn-54	x	x		x	
Cr-51				x	
Fe-55, Fe-59	x	x		x	
Co-57, Co-58, Co-60	x	x		x	
Ni-63	x	x		x	
Zn-65	x	x			
Ga-67				x	
Sr-89, Sr-90	x	x		x	
Tc-99	x	x	x	x	
Tc-99m				x	
Ru-106	x	x			
Ag-110m	x	x			
In-111				x	
Sb-125	x	x		x	
I-123, I-125, I-129, I-131	x	x		x	
Cs-134, Cs-137	x	x		x	
Ce-144	x	x			
Eu-152, Eu-154, Eu-155	x	x			
Ir-192				x	
Tl-201				x	
Ra-226, Po-210				x	x
U-238, U-234, U-235			x	x	x
Pu-238, Pu-239, Pu-240, Pu-241	x	x	x	x	
Am-241	x	x	x	x	
Cm-243, Cm-244	x	x	x		
Natural-U			x	x	x
Natural-Th			x	x	x
Enriched-U and Depleted -U			x	x	

Note: All "material licensees" include manufacturers of sealed sources and radio-labeled compounds, nuclear pharmacies, R&D facilities, academic institutions, medical centers, nuclear laundries, government laboratories, decontamination services, and commercial service organizations supporting licensees.

Solid materials not located in restricted or impacted areas, and considered to be free of radioactivity resulting from licensed operations, are not currently required to be part of a disposition radiological survey program. Such materials can include furniture, glass bottles, paper, equipment, or trash in administrative buildings or office areas. This rulemaking does not propose to alter this approach and, therefore, these materials also are not the subject of the Proposed Action. In this Draft GEIS, these materials are referred to as “clean.”

Contamination is characterized by a large mass of potentially clearable material and a large mass of materials with very high contamination levels (SC&A 2003). Little material is expected to have intermediate contamination levels. The high end contamination is typically associated with areas where contamination is inevitable (e.g., areas with equipment used to process nuclear materials).

Description of NRC-Licensed Facilities

The facilities that generate the solid materials and are the subject of this Draft GEIS are all licensed facilities (about 21,000 sites/facilities) and include the following:

- Commercial Nuclear Power Reactors
  - Currently licensed (104)
  - Formerly licensed, excluding reactors which have largely completed DECON[2] (17)
- Non-Power Licensed Reactors (36)
- Fuel Cycle Facilities
  - Uranium mills and *in situ* leach facilities (16)
  - Conversion/enrichment plants (4)
  - Fuel fabrication plants (7)
  - Independent spent fuel storage installations (28)
- Material Licensees (21,000)
- Complex Materials Decommissioning Sites (43[3])

The number of licensed facilities is constantly changing because every year new facilities receive operating licenses and some licenses are terminated. This listing of facilities is based primarily on data compiled by the NRC in its *2002 Information Digest* (NRC 2002c) and as such represents a snapshot at that instant in time.

[2] DECON is an NRC Classification for nuclear facilities in which “the equipment, structures, and portions of a facility and site that contain radioactive contaminants are removed or decontaminated to a level that permits termination of the license after cessation of operations.”

[3] Formerly known as SDMP sites. The number of sites indicated does not include reactor sites. The NRC has eliminated the designations of the “Site Decommissioning Management Plan (SDMP),” “SDMP Program,” or “SDMP sites.” (Federal Register, June 17, 2004, Vol. 69, No. 116, p. 33946). Such sites are now referred to as “complex decommissioning sites.”

1. Commercial Nuclear Power Reactors

Commercial nuclear power reactors include boiling water reactors (BWRs) and pressurized water reactors (PWRs). In order to characterize the solid materials that could be released from commercial nuclear power reactors, reference facilities were developed for both BWRs and PWRs and the results were scaled to cover all the reactors (SC&A 2003).

Reference Boiling Water Reactor

The reference BWR consists of three principal buildings where radioactive contamination may be present: the Reactor Building, the Turbine Generator Building, and the Radwaste and Control Building.

The Reactor Building contains the nuclear steam supply system and its supporting systems. It is constructed of reinforced concrete capped by metal siding and roofing supported by structural ferrous metals. The building surrounds the primary containment vessel, which is a free-standing ferrous metals structure. The exterior dimensions of the Reactor Building are approximately 42 m by 53 m in plan, with 70 m above grade and 10.6 m below grade to the bottom of the foundation.

The Turbine Generator Building, which contains the power conversion system equipment and supporting systems, is constructed of reinforced concrete capped by ferrous metals-supported metal siding and roofing. This structure is approximately 60 m by 90 m in plan and 42.5 m high.

The Radwaste and Control Building houses, among other systems, the condenser offgas treatment system, the radioactive liquid and solid waste systems, the condensate demineralizer system, the reactor water cleanup demineralizer system, and the fuel-pool cooling and cleanup demineralizer system. The building is constructed of reinforced concrete and structural ferrous metals and has metal siding and roofing. This structure is approximately 64 m by 49 m in plan and 32 m in overall height.

Several additional buildings make up the reference BWR complex. These include the Diesel Generator Building, Service Building, Circulating Water Pump House, Spray Pond Complex, Makeup Water Pump House, the yard, and other buildings (i.e., Office Building, Warehouse, Guard House, and Gas Bottle Storage Building). These buildings are assumed not to be radioactively contaminated. They would generally fall into the clean category in the MARSSIM definition of a non-impacted area.

Reference Pressurized Water Reactor

The principal structures at the reference PWR power station are the Reactor Building, Fuel Building, Auxiliary Building, Control Building, and Turbine Building.

The Reactor Building houses the nuclear steam supply system. Since its primary purpose is to provide a leak-tight enclosure for normal as well as accident conditions, it is frequently referred to as the containment building. Major interior structures include the biological shield, pressurizer cubicles, and a ferrous metals-lined refueling cavity. Supports for equipment, operating decks, access stairways, grates, and platforms are also part of the containment structure internals. The Reactor Building is in the shape of a right circular cylinder approximately 64 m tall and 22.5 m in diameter. It has a hemispherical dome, a flat base slab with a central cavity, and an instrumentation tunnel.

The Fuel Building, approximately 27 m tall and 19 m long by 54 m wide, is a ferrous metals-reinforced concrete structure with four floors. This building contains the spent-fuel storage pool and its cooling system, much of the chemical and volume control system, and the solid radioactive waste handling equipment. Major ferrous metals structural components include fuel storage racks and liners, support structures for fuel handling, and components, ducts, and piping associated with air conditioning, heating, cooling, and ventilation.

The Auxiliary Building, approximately 30 m tall with lateral dimensions of 19 m by 35 m, is a ferrous metals and reinforced concrete structure with two floors below grade and four floors above grade. Principal systems contained in the Auxiliary Building include the liquid radioactive waste treatment systems, the filter and ion exchanger vaults, waste gas treatment system, and the ventilation equipment for the Reactor, Fuel, and Auxiliary Buildings.

Other major building structures with substantial inventories of metals include the Control Building and Turbine Building. The principal contents of the Control Building are the reactor control room, as well as process and personnel facilities. The principal systems in the Turbine Building are the turbine generator, condensers, associated power production equipment, steam generator auxiliary pumps, and emergency diesel generator units.

2. Non-Power Reactors

Non-power reactors (NPRs) come in many varieties and forms, with most being either pool-type or tank-type. Many are located at universities and research organizations. Pool-type reactors have a core immersed in an open pool of water. The pools typically provide about 20 ft of water above the core to allow cooling and radiation shielding. At pool-type NPRs, the operating core and fuel can be observed through the pool water. Tank-type reactors have a core in a tank with water, sealed at the top. Non-power reactors are also categorized by fuel type: plate-type fuel, TRIGA (Training, Research, Isotopes, General Atomics), or AGN (Aerojet General Nucleonics). Plate-type fuel consists of several thin plates containing a uranium mixture clad with aluminum formed into an assembly. This geometry promotes efficient heat removal and the ability to provide a high-neutron density. TRIGA fuel is in the shape of rods and consists of a uranium and zirconium hydride mixture. AGNs are compact, self-contained, low-power (<5 watts) tank-type reactors. The 10-in diameter core consists of uranium oxide powder embedded in a polyethylene moderator.

3. Uranium Mills

Nuclear fuel cycle facilities include uranium mills, uranium hexafluoride production facilities, fuel fabrication facilities, and uranium enrichment facilities.

NRC currently licenses 16 uranium recovery facilities[4] under 10 CFR Part 40, including 12 conventional uranium mills and 4 *in situ* leach facilities. In addition, some milling sites are licensed by Agreement States. Most conventional uranium mills have been shut down and are undergoing decommissioning. These mills are not likely to be significantly affected by any future NRC regulations relating to the release of solid materials from regulatory control, since dismantlement will likely be well advanced or completed prior to any rulemaking. One conventional mill is on standby status and two are operating. Based on the likely approach to decommissioning, where there is little or no salvageable equipment and most materials are buried in onsite tailings piles or at other approved sites, the quantities of potentially clearable materials from uranium mills are expected to be small. Some licensees may attempt to sell or transfer larger items such as tanks, and office trailers and construction equipment.

Of the four NRC-licensed *in situ* leach facilities, one has been shut down and is undergoing decommissioning. The shutdown facility is unlikely to be affected by the Proposed Action, since dismantlement is expected to be largely completed prior to issuance of any final rule. Two *in situ* leach facilities are operating, one is decommissioning, and one is not yet built. Some large resin and chemical tanks and pumps may be available for recycle/reuse when these facilities are ultimately decommissioned. Contaminated equipment and plastic piping are likely to be disposed of in tailings piles or at other licensed disposal sites. Disposition of structures and clean equipment could be affected by the Proposed Action.

4. Uranium Hexafluoride Production Facilities

Most nuclear reactors require uranium to be enriched from its natural isotopic composition of approximately 0.7 percent U-235 (most of the rest being U-238) to 3.5-4 percent U-235. To enrich uranium in a diffusion plant, it must first be converted to a gaseous form, and the standard way of achieving this is to convert the uranium oxides to uranium hexafluoride (UF_6). The reference UF_6 production facility consists of a main building, a solvent extraction facility, a warehouse, a cooling tower, retention lagoons, and other storage areas.

The only operating UF_6 conversion facility in the United States is managed by Honeywell in Metropolis, Illinois. The Sequoyah Fuels Corporation facility in Gore, Oklahoma, was shut down in 1993 and is currently awaiting decommissioning. The NRC license for the Honeywell facility expires on June 30, 2005. Closure of that facility at that time would force reliance on foreign sources of conversion capacity. To ensure continued domestic UF_6 production capability, the Honeywell license would need to be renewed, or a new facility would need to be constructed and licensed to operate by June 2005. However, DOE is currently in the construction phase for a UF_6 conversion facility on the site of the existing Portsmouth Gaseous Diffusion Plant (uranium enrichment plant) in Portsmouth, Ohio. It is not yet clear exactly when this facility will be operational.

[4] A uranium mill tailings waste disposal facility in South Clive, Utah, is also licensed under the regulation.

5. Uranium Enrichment Facilities

DOE leases uranium enrichment facilities in Paducah, Kentucky, and Portsmouth, Ohio, to the U.S. Enrichment Corp. These facilities are administered under NRC regulations at 10 CFR Part 76. DOE's K-25 enrichment facility in Oak Ridge, Tennessee, has been shut down and is undergoing decommissioning. The Portsmouth plant was shut down in March 2001 and DOE plans to keep the plant in a cold standby basis permitting rapid reopening. Recently, both Louisiana Energy Services (Lea County, New Mexico) and USEC, Inc. (site of the current Portsmouth Gaseous Diffusion Plant) have submitted license applications to the NRC to construct and operate a gas centrifuge uranium enrichment facility. The gas centrifuge uranium enrichment process uses a large number of rotating cylinders in series to enrich uranium in its U-235 isotope. Since DOE has responsibility for decommissioning and dismantling these plants, they are not considered here.

6. Fuel Fabrication Facilities

Fabrication is the final step in the process used to produce uranium fuel. This process converts enriched UF_6 into a solid form of uranium suitable for use in a nuclear reactor. Fabrication of reactor fuel consists of three basic steps: the chemical conversion of UF_6 to uranium dioxide (UO_2) powder; the ceramic process that converts UO_2 powder to pellets; and the mechanical process that loads the fuel pellets into rods and constructs finished fuel assemblies.

There are six uranium fuel fabrication facilities currently licensed to operate by the NRC, plus one in decommissioning and a mixed oxide (MOX) fuel fabrication facility currently under development. An application has been submitted to NRC for authority to construct a MOX facility. The application is under review by the NRC. The reference uranium fuel fabrication facility is based primarily on the Global Nuclear Fuel facility in Wilmington, North Carolina.

7. Independent Spent Fuel Storage Installations (ISFSI)

An ISFSI is a complex designed and constructed for the interim storage of spent nuclear fuel. As of August 2003, there are 28 licensed facilities. In addition, there are 19 soon-to-be-built or operational facilities and a further four being considered in addition to the proposed Private Fuel Storage facility in Tooele, UT. There is also a single wet storage facility in Morris, Illinois, operated by the General Electric Company.

ISFSIs may be initially licensed for a period of up to 20 years. The license may also be renewed for an additional 20 years. Therefore, it is expected that the materials contained in the above ISFSIs would be available for release 20 or 40 years after the ISFSI start-up dates. However, a recent study has determined that extending the storage period to 100 years would have no adverse impacts (Einziger et al. 1998). Conversely, fuel may be removed from storage prior to the end of the licensed lifetime of the ISFSI, if a high-level waste (HLW) repository becomes available. Spent fuel may be stored in either a wet or dry environment; the various techniques include: Concrete Casks, Horizontal Storage Modules (HSM), Metal Casks, Pool (Wet) Storage, and Modular Vault Dry Storage (MVDS).

8. Materials Licensees

The NRC Information Digest (NRC 2002c) indicates a total of 21,175 medical, academic and industrial materials licensees in the United States. Of these, 23 percent are NRC licensees and 77 percent are licensed by Agreement States.

Profiles were prepared of materials licensees potentially affected by the Proposed Action (SC&A 2003). These profiles do not include those licenses that authorize only possession and use of licensed materials in sealed sources or other non-dispersible forms, such as plated disks and foils because for these licensees, operation and decommissioning would normally entail no decontamination efforts. At decommissioning the licensed source would simply be removed from the facility and disposed of in accordance with NRC regulations. Elimination of these types of licensees resulted in a population of 3,017 non-reactor licenses that are potentially affected by the Proposed Action. Based on this understanding of the universe of potentially affected non-reactor, non-sealed source NRC licensees, this section addresses four broad categories of licensees: large medical centers, research and development laboratories, nuclear pharmacies (including both manufacturers and regional and local distributors), and manufacturers of sources and radio-labeled compounds.

Large Medical Centers

The inventory of materials in the reference room of a large medical center is about 2,300 kg (5,000 lb). The total inventory of materials in large medical centers in the U.S. is about 440,000 metric tons (480,000 tons). Much of this mass would be trash (e.g., plaster board, floor tiles) rather than recyclable materials. Items such as refrigerators and storage cabinets could potentially be released for reuse.

Research and Development Laboratories

In many respects, research and development (R&D) laboratories are similar to the research laboratories at large medical facilities. R&D facilities using radioactive materials cover a broad range of activities, including the use of laboratories or health treatment facilities that use radioisotopes. Both short-lived (^{3}H) and long-lived isotopes (^{14}C) may be used. The reference R&D laboratory facility includes rooms for synthesis of labeled compounds and for preparing radioactive samples, a laboratory, a counting room, and a storage room. In addition to the contaminated structural material, the reference R&D facility also contains furniture and equipment.

Nuclear Pharmacies

The NRC issues commercial nuclear pharmacy licenses pursuant to 10 CFR Part 30 and 10 CFR 32.72, for the possession and use of radioactive materials for the manufacture, preparation, or transfer for commercial distribution of radiopharmaceuticals (radioactive drugs) containing byproduct material for medical use under Part 35. Radiopharmaceuticals produced from NORM or accelerator-produced radionuclides are not within the regulatory authority of the NRC, although they may be subject to State licensing requirements. Preparation includes the making of radiopharmaceuticals from reagent kits and from raw materials. Typically, nuclear pharmacies are also authorized to transfer for commercial distribution (per 10 CFR 31.11) in vitro test kits, radiopharmaceuticals to licensees authorized to possess them for other than human medical use (i.e., veterinary medicine and research licensees), and radiochemicals to those licensees authorized to possess them, pursuant to 10 CFR Part 30. Additionally, nuclear pharmacies are authorized to redistribute (transfer) sealed sources for calibration and medical use initially distributed by a manufacturer licensed pursuant to 10 CFR 32.74. The NRC database identifies 52 nuclear pharmacies.

For nuclear pharmacies, decommissioning for license termination will typically involve the removal of all sealed sources and depleted uranium and maintenance of active radiological control of the facility until the longest half-life material used at the facility have decayed to an acceptable level. A confirmatory survey after the appropriate elapsed time would then complete decommissioning efforts. Nuclear pharmacies are not expected to be significant sources of potentially clearable materials for recycle or reuse.

Manufacturers of Sources and Radio-Labeled Compounds

The sealed source manufacturing process is a hand operation that is carried out in buildings which contain a number of small laboratories, each of which is devoted to a specific process and/or isotope. The reference sealed source manufacturer is a laboratory which processes ^{137}Cs and ^{60}Co. Contaminated facilities associated with the reference sealed source manufacturer include: hot cells, fume hoods, workbenches, sinks, laboratory floor and wall areas, and building areas used for storage of waste drums. The Commission's license tracking system identified 63 sealed source and radio-labeled compound manufacturers licensed by the NRC. As is the case for R&D labs, the individual facilities that make up this category are very diverse. Not all facilities within this category manufacture Co-60 sealed sources. Some facilities manufacture radio-labeled compounds and therefore may have more in common with the hospital and R&D laboratories.

9. Complex Materials Decommissioning Sites

Forty-three complex (not routine) materials decommissioning sites are currently being remediated. At many of these locations, the only issue is soil with elevated levels of radioactivity. In addition, building materials and slags will be released during cleanup operations. Some of the slags may be processed for metals recovery.

Inventories of Solid Materials for the Rulemaking Alternatives

This section summarizes the characteristics of solid materials generated largely from commercial nuclear reactor facilities and considered in the collective dose assessment (SC&A 2003). Material characteristics are provided in terms of the total mass (tons) of each material (ferrous metals, concrete, and trash) released from commercial reactor facilities and the total activity (curies) for each alternative. SC&A 2003 describes the detailed information for these inventory estimates.

1. No Action Alternative

The total mass and activity of material generated from commercial nuclear reactor facilities forms the baseline solid material inventory for all the alternatives. Under the No Action Alternative, for example, a total of 2.06 million tons of ferrous metals generated from commercial nuclear reactor facilities would be released for recycling, out of a total estimated amount of scrap ferrous metals generated of approximately 2.5 million tons. The remaining 0.44 million tons of ferrous metals generated from commercial nuclear reactor facilities but not released for recycling would be disposed of as LLW in a licensed disposal facility. Similar calculations apply to the other materials (concrete and trash).

Table F-2 provides an estimate of the total mass and total activity of solid material released from commercial reactor facilities under the No Action Alternative. For the No Action Alternative, the mass of material released is dominated by concrete, which represents approximately 90 percent of the total mass. However, the total activity of the material is represented primarily by the ferrous metals and trash, which represent almost 94 percent of the total activity.

Table F-2 Total Activity and Total Mass of Material Released from Commercial Nuclear Reactor Facilities: No Action Alternative

No Action Alternative	Activity (Ci)	Mass (million tons)
Ferrous metals	1.76	2.06
Concrete	0.24	16.20
Trash	2.32	0.02
Aluminum	0.0008	0.000173
Copper	0.043	0.005326
Total for All Materials	4.36	18.29

Source: SC&A 2003, Tables 5.8, 10.3, 10.4, and 10.7.

2. Unrestricted Release Alternative

Tables F-3 and F-4 provide estimates of the total mass and total activity of solid material released from commercial reactor facilities under the Unrestricted Release Alternative. The values in these tables are based on summations from statistical sampling and mean (average) values are used. Mass and activity values are reported for both material-specific and material-independent cases. The material-specific case applies different radionuclide concentration limits to the different materials for each radionuclide, while the material-independent case applies the same radionuclide concentration limit to all of the materials for each radionuclide.

The material-specific case employs NUREG-1640 (NRC 2003d) normalized doses that are specific to each type of material (i.e., ferrous metals, concrete, and trash) and each radionuclide. This approach derives the maximum radionuclide concentration in each material. For example, the radionuclide concentration for Co-60 for the 1 mrem/yr dose option differs for ferrous metals, concrete, and trash; i.e., the allowable radionuclide concentration at which material could be released for unrestricted release differs depending on the material.

Table F-3 Total Mass (million tons) of Material Released from Commercial Nuclear Reactor Facilities: Unrestricted Release Alternative

	Dose Option				
	0.03 mrem/yr	**0.1 mrem/yr**	**1 mrem/yr**	**10 mrem/yr**	**RS-G-1.7[1]**
Ferrous metals					
Unrestricted/Material-Specific	0.970	1.490	2.20	2.45	
Unrestricted/Material-Independent	0.441	0.786	1.74	2.30	1.74
Concrete					
Unrestricted/Material-Specific	15.0	17.6	19.6	19.8	
Unrestricted/Material-Independent	15.0	17.6	19.6	19.8	19.6
Trash					
Unrestricted/Material-Specific	0.014	0.021	0.041	0.066	
Unrestricted/Material-Independent	0.0002	0.0004	0.002	0.006	0.002
Total for All Materials					
Unrestricted/Material-Specific	16	19.1	21.9	22.3	
Unrestricted/Material-Independent	15.5	18.4	21.4	22.1	21.4

[1] Based on calculations by NRC, the mass of material for the RS-G-1.7 dose option is assumed to be the same as for the 1 mrem/yr dose option.

Source: SC&A 2003, Tables 10.3 and 10.7.

Table F-4 Total Activity (Curies) Released from Commercial Nuclear Reactor Facilities: Unrestricted Release Alternative

	Dose Option				
	0.03 mrem/yr	**0.1 mrem/yr**	**1 mrem/yr**	**10 mrem/yr**	**RS-G-1.7[1]**
Ferrous metals					
Unrestricted/Material-Specific	0.092	0.395	2.86	12.74	
Unrestricted/Material-Independent	0.008	0.048	0.745	4.33	1.49
Concrete					
Unrestricted/Material-Specific	0.168	0.401	1.49	1.73	
Unrestricted/Material-Independent	0.168	0.401	1.49	1.73	2.98
Trash					
Unrestricted/Material-Specific	0.588	2.56	36.79	523.81	
Unrestricted/Material-Independent	0.00001	0.00005	0.0015	0.043	0.003
Total for All Materials					
Unrestricted/Material-Specific	0.865	3.40	41.32	538.60	
Unrestricted/Material-Independent	0.194	0.497	2.43	6.42	4.86

[1] Based on calculations by NRC, the total activity release for the RS-G-1.7 material-independent scenario is assumed to be two times that of the total activity released for the 1 mrem/yr dose option.

Source: SC&A 2003, Tables 5.8 and 10.7.

For the material-independent case, the most limiting normalized doses in NUREG-1640 are used to define the radionuclide concentration level and, as a result, the levels that correspond to a given radionuclide are the same for all materials. For example, the presence of Co-60 in concrete (used in road building) results in the most limiting dose factor as compared to the presence of Co-60 in ferrous metals, copper, or aluminum. The material-independent case is thus more restrictive than the material-specific case and the quantity of material and the collective radiation doses to the members of the public are lower for the material-independent case. More details can be found in Appendix D for both cases - material-specific results (Case A) and material-independent results (Case B) (see Tables D-1 to D-3).

For the Unrestricted Release Alternative using a material-specific case, as for the No Action Alternative, the mass of material released is dominated by concrete, which represents approximately 90 percent of the total mass. The total activity of the material is represented primarily by the ferrous metals and trash, which represent approximately 95 percent of the total activity, for the 1 mrem/year dose option.

Using a material-independent case, concrete is the limiting material for radionuclide concentrations and the total mass of ferrous metals and the total mass and activity of trash released are lower than amounts that would be released under material-specific conditions. Using a material-independent case, the ferrous metals and concrete released represent greater than 99 percent of the activity, and trash represents less than 0.1 percent of the activity.

3. EPA/State-Regulated Disposal Alternative

Tables F-5 and F-6 provide estimates of the total mass and total curies of solid material released from commercial nuclear reactor facilities under the EPA/State-Regulated Disposal Alternative. The values in these tables are based on summations from statistical sampling and mean (average) values are used. For the EPA/State-Regulated Disposal Alternative without trash incineration, as for the No Action Alternative and Unrestricted Release Alternative, the mass of material released is dominated by concrete, which represents 93 percent of the total mass. The total activity of the material released is represented primarily by the ferrous metals and trash, which represent almost 95 percent of the total activity, for the 1 mrem/year dose option. The mass and activity released for the EPA/State-Regulated Disposal Alternative with and without trash incineration are assumed to be the same.

4. Low-Level Waste (LLW) Disposal Alternative

Under the LLW Disposal Alternative, none of the potentially clearable solid material would be released for either unrestricted use or EPA/State-regulated disposal. All of the material would be classified as LLW and would be transported to and disposed of in a LLW disposal facility. The total mass and activity of material that would be disposed of in LLW disposal facilities under this Alternative is summarized in Table F-7.

Table F-5 Total Activity (Curies) Released from Commercial Nuclear Reactor Facilities: EPA/State-Regulated Disposal Alternative

	Dose Option				
	0.03 mrem/yr	**0.1 mrem/yr**	**1 mrem/yr**	**10 mrem/yr**	**RS-G-1.7[1]**
Ferrous metals	0.484	1.46	7.09	23.81	14.18
Concrete	0.201	0.460	1.67	1.73	3.34
Trash	0.588	2.56	36.79	523.81	73.58
Total for All Materials	1.29	4.53	45.74	549.67	91.48

[1] Based on calculations by NRC, the total activity release for the RS-G-1.7 material-independent scenario is assumed to be two times that of the total activity released for the 1 mrem/yr dose option.

Source: SC&A 2003, Tables 5.8 and 10.4.

Table F-6 Total Mass (million tons) of Material Released from Commercial Nuclear Reactor Facilities: EPA/State-Regulated Disposal Alternative

	Dose Option				
	0.03 mrem/yr	**0.1 mrem/yr**	**1 mrem/yr**	**10 mrem/yr**	**RS-G-1.7[1]**
Ferrous metals	1.57	2.00	2.38	2.48	2.38
Concrete	15.6	17.9	19.7	19.8	19.7
Trash	0.014	0.021	0.041	0.066	0.041
Total for All Materials	17.2	19.9	21.2	22.3	21.2

[1] Based on calculations by NRC, the mass of material for the RS-G-1.7 dose option is assumed to be the same as for the 1 mrem/yr dose option.

Source: SC&A 2003, Tables 10.3 and 10.7.

Table F-7 Mass and Radioactivity of Materials Released from Commercial Nuclear Reactor Facilities: LLW Disposal Alternative

Material	Total Mass (tons)	Contained Radioactivity (Ci)
D&D Ferrous metals	2,117,906	11
D&D Ferrous metals (Decon)	285,212	284
Operating Ferrous metals	95,793	95.3
Total Ferrous metals	2,498,911	390.3
D&D Concrete	19,877,341	1.74
Trash	323,023	2,560
Aluminum	212	0.006
Copper	6,584	0.31
Total	22,706,071	2,951

Source: SC&A 2003, Tables 5.8, 8.6, and 10.3.

5. Limited Dispositions Alternative

The mass and activity of concrete recycled under the Limited Dispositions Alternative would be the same as for the Unrestricted Release Alternative. The mass and activity of other disposed materials would be the same as for the EPA/State-Regulated Disposal Alternative.

Characterization of Solid Materials Generated from Licensed Facilities Other than Commercial Reactors

The mass and activity values described above and the collective dose results are based on material generated only from commercial nuclear reactor facilities. This is because smaller amounts of solid materials would be generated from licensed facilities other than commercial nuclear reactor facilities and released for either recycling or disposal. Trash is the significant material for these other licensed facilities and, therefore, ferrous metals and concrete are not included here. Table F-8 provides a summary of the total estimated mass and activity of trash generated from licensed facilities other than commercial nuclear reactor facilities for the No Action and Unrestricted Release Alternatives.

Table F-8 Comparison of Mass and Activity of Trash Released from Commercial Nuclear Reactor Facilities with Trash Generated from Other Licensed Facilities

Alternative and Dose Option	Total Activity Released (Ci)			Total Mass Released (million t)		
	Nuclear reactors	Other licensees	Total	Nuclear reactors	Other licensees	Total
No Action	2.32	0.976	3.296	0.02	0.273	0.293
Unrestricted Release						
RS-G-1.7	73.6	30.8	104.4	0.041	0.549	0.59
10 mrem/yr	524	220	744	0.066	0.886	0.952
1 mrem/yr	36.8	15.4	52.2	0.041	0.549	0.59
0.1 mrem/yr	2.56	1.08	3.64	0.021	0.282	0.303
0.03 mrem/yr	0.588	0.247	0.835	0.014	0.183	0.197

Source: SC&A 2003, Table 5.6.