EA-1042; Environmental Assessment Proposed Changes to the Sanitary Sludge Land Application Program on the Oak Ridge Reservation

LIST OF TABLES

ACRONYMS

This list represents acronyms for the entire document; however, for the reader's convenience, individual lists are also presented for Appendixes C-F.

ALARA as low as reasonably achievable

CEQ Council on Environmental Quality

COC constituent of concern

CSF cancer slope factor

DOE U.S. Department of Energy

EA environmental assessment

EFPC East Fork Poplar Creek

Energy Research Lockheed Martin Energy Research, Inc.

Energy Systems Lockheed Martin Energy Systems, Inc.

EPA U.S. Environmental Protection Agency

HEAST Health Effects Assessment Summary Tables

HI hazard index

HQ hazard quotient

IRIS Integrated Risk Information System

IWMF Interim Waste Management Facility

LAA land application approval

LET linear energy transfer

LOAEL Lowest Observed Adverse Effect Level

MSL mean sea level

NCP National Oil and Hazardous Substances Pollution Contingency Plan

NEPA National Environmental Policy Act

NOAEL No Observed Adverse Effect Level

NPDES National Pollutant Discharge Elimination System

NRC National Research Council

ORNL Oak Ridge National Laboratory

ORR Oak Ridge Reservation

PCB polychlorinated biphenyl

POTW Publicly Owned Treatment Works

RCRA Resource Conservation and Recovery Act

RESRAD Residual Radioactivity computer model

RfC reference concentration

RfD reference dose

ROI Region of Influence

SAIC Science Applications International Corporation

SHPO State Historic Preservation Officer

SWSA Solid Waste Storage Area

TDEC Tennessee Department of Environment and Conservation

TWRA Tennessee Wildlife Resources Agency

USFWS U.S. Fish and Wildlife Service

EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) proposes to raise the sludge land application loading limits from the current, self-imposed conservative 48 metric tons/ha (22 tons/acre) lifetime loading to the U.S. Environmental Protection Agency (EPA)-approved and Tennessee Department of Environment and Conservation (TDEC)-permitted level of 110 metric tons/ha (50 tons/acre). In addition, DOE proposes increasing radionuclide loading above the conservative twice background (2×) level to dose-based Residual Radioactivity limits. DOE proposes to add Oak Ridge National Laboratory (ORNL) and the K-25 Site as industrial customers of the city of Oak Ridge Publicly Owned Treatment Works (POTW), thus adding ORNL and K-25 Site pretreated sewage sludge to the existing sewage sludge land application program on the Oak Ridge Reservation (ORR). The program has been in operation since 1983. The sludge would be trucked from these plants to the city's sewage treatment plant for treatment and subsequent addition to the existing sludge land application program. The total additional sludge would amount to an increase of 4 to 5%. The ORNL and K-25 Site sewage sludges would have to meet similar pretreatment standards and prescribed sanitary discharge limits as required of the Y-12 Plant and other industrial sewage generators located in the city in order to be compatible with the city's industrial sewage pretreatment program.

Under the no-action alternative, ORNL and K-25 Site sewage sludge would not be transferred to the city of Oak Ridge POTW. Sewage sludge for these two facilities would continue as currently practiced [i.e., sewage sludge dewatering, air drying (K-25 Site only) or thermal drying (ORNL only), and aboveground disposal in metal containers]. The city of Oak Ridge would continue to apply sewage sludge on active and previously utilized sites until the approved loading limit of 48 metric tons/ha (22 tons/acre) is reached at these sites, requiring the city to use other sludge management methods, such as alternative (non-ORR) land application sites. These non-federal activities are beyond the scope of this environmental assessment. The no-action alternative provides a baseline for comparison with the proposed action and alternatives.

An independent DOE sludge land application program alternative would combine the continuation of sewage sludge land application on the ORR by the city of Oak Ridge and the initiation of an independent DOE application program for ORNL and K-25 Site sewage sludges. Application within both programs would continue on active and previously utilized land application sites on the ORR.

Another alternative would involve developing an independent DOE sludge land application program for the beneficial use of ORNL and K-25 Site sewage sludges along with discontinuing the city of Oak Ridge's sewage sludge application on the ORR. DOE's land application program would continue to use active and previously utilized application sites on the ORR, while the city's program would be required to obtain application sites off the ORR or use an alternative sludge management method.

Several other alternatives to the proposed action were considered: composting of ORNL and K-25 Site sludge, shallow land burial, incineration, and off-site disposal. All were eliminated from further consideration for some or all of the following reasons: higher environmental risks, significantly higher cost, failure to employ beneficial use of sewage sludge, and longer-term planning and coordination required than could satisfy the current time frame.

Minimal impacts to biota, natural resources, and humans would be expected under the proposed action, no action, or the action alternatives, based on the evaluation of socioeconomic and environmental factors. Combined chemical and radiological impacts to human health would be minimal and within or below EPA target ranges. Transportation risk would be very low.

GLOSSARY

Adsorption Adhesion of molecules of gas, liquid, or dissolved solids to a surface.

Anaerobic A life or process that occurs in, or is not destroyed by, the absence of oxygen.

Aeration A process that promotes biological degradation of organic water. The process may be passive (as when waste is exposed to air) or active (as when a mixing or bubbling device introduces the air).

Buffer zones An area designated to separate certain features, such as streams, lakes, or roads, from impacts from sludge application. The width of buffer zones for sludge application is determined by the Tennessee Department of Environment and Conservation.

Demographics Statistics relating to the dynamic balance of a population, especially with regard to density, distribution, and capacity for expansion or decline.

Desiccation Drying out; plants or insects or microorganisms may dry out to the extent that they die.

Heavy metals Metallic elements with high atomic weights, for example, mercury, chromium, cadmium, arsenic, and lead. They can damage living things at low concentrations and tend to accumulate in the food chain.

Herbaceous Plants having little or no woody tissue and persisting usually for a single growing season.

Hydrogeology The geology of groundwater, with particular emphasis on the chemistry and movement of water.

Hydrology The science dealing with the properties, distribution, and circulation of water.

Influent Water, wastewater, or other liquid flowing into a treatment plant.

Inorganic chemicals Chemical substances of mineral origin, not of basically carbon structure.

Natural areas Areas on the Oak Ridge Reservation that have been established to protect state or federally listed rare species and species under status review for federal listing that occur on the Oak Ridge Reservation. The Natural Areas consist of a core area (actual location of the plants) and a buffer area for habitat protection.

Organic chemicals Substances containing mainly carbon, hydrogen, and oxygen.

Pathogens Microorganisms that can cause disease in other organisms or in humans, animals, and plants. They may be bacteria, viruses, or parasites and are found in sewage.

Potable water Water that is safe for drinking and cooking.

POTW Publicly owned treatment works: a waste treatment works, usually owned by a unit of local government and designed to treat domestic wastewaters.

Radionuclide Radioactive element, characterized according to its atomic mass and atomic number, that can be man-made or naturally occurring. They can have a long life as soil or water pollutants.

Reference areas Areas on the Oak Ridge Reservation that are representative of the vegetational communities of the southern Appalachian region or that possess unique biotic features. These areas are important as sources of baseline information for long-term observations and monitoring. They are set aside for the exclusive use of nonmanipulative environmental research.

Sewage sludge Sludge produced at a POTW, the disposal of which is regulated under the Clean Water Act.

Transient Passing through or by a place with only a brief stay.

Waters of the state Any and all waters, public or private, on or beneath the surface of the ground, which are contained within, flow through, or border upon Tennessee or any portion thereof except those bodies of water confined to and retained within the limits of private property in single ownership which do not combine or effect a junction with natural surface or underground waters.

1. INTRODUCTION

1.1 PURPOSE AND NEED FOR AGENCY ACTION

The purpose of this proposed U.S. Department of Energy (DOE) action is to increase land loading limits and to add the sanitary sewage sludges from Oak Ridge National Laboratory (ORNL) and the K-25 Site wastewater treatment plants pretreatment processes to the existing sludge land application program on the Oak Ridge Reservation (ORR) operated by the city of Oak Ridge. This action would implement a more effective method of managing ORNL and K-25 Site sanitary sewage sludge than the current method, which is to place the sludge in limited-availability, high-cost waste storage or disposal on the ORR. ORNL, the K-25 Site, and the Y-12 Plant are located on the ORR in Oak Ridge, Tennessee (Fig. 1.1). ORNL is operated by Lockheed Martin Energy Research, Inc. (Energy Research), and the K-25 Site and the Y-12 Plant are operated by Lockheed Martin Energy Systems, Inc. (Energy Systems) for DOE. This proposed action would also continue the beneficial land application of sanitary sewage sludge* (1) generated by the Oak Ridge Publicly Owned Treatment Works (POTW)*. The POTW is also shown in Fig. 1.1

This action is driven by (1) the need to reduce the high cost of current sludge management at ORNL and the K-25 Site, (2) the requirement for expanded capacity to the current permitted limits of existing active and previously utilized sites for land application, and (3) the federal policy to consider beneficial use of sewage sludge as a soil amendment.

The U.S. Environmental Protection Agency (EPA) supports a policy whereby federal land management agencies should consider beneficial use of municipal sewage sludge for fertilizer, soil conditioner, or other soil amendment uses, when such uses enhance resources on federal lands and are cost effective (56 *FR* 30448 Interagency Policy on Beneficial Use of Sewage Sludge 1991). Evidence from the existing sludge land application program on the ORR demonstrates that sludge application has enhanced resources (i.e., even single applications of sludge have shown long-term positive growth response of trees) (Van Miegroet, Boston, and Johnson 1991).

1.2 BACKGROUND

Under an agreement with DOE, the city of Oak Ridge has been applying municipal sewage sludge as a beneficial soil amendment on the ORR since 1983 (Energy Systems 1993). The sludge characteristics are described in Sect. 2.1.2, and Tables 2.1 through 2.8 show the concentrations of inorganic chemicals*, heavy metals*, organic chemicals*, and radionuclides*, respectively. Although Oak Ridge POTW sewage sludge contains trace amounts of heavy metals and radionuclides, as do most municipal sewage sludges, it is considered a non-Resource Conservation and Recovery Act (RCRA), nonradioactive waste that is regulated under Sect. 405 of the Clean Water Act (33 *USC* 1345) and Tennessee Department of Environment and Conservation (TDEC), Division of Water Pollution Control (PAI 1994). The Y-12 Plant, which has no sewage treatment plant, currently contributes ~20% of the Oak Ridge POTW's total raw sewage influent* (DOE 1994b).

Biosolids recycling or land application, which are the terms EPA uses for sewage sludge applied to land for its beneficial properties (58 *FR* 9321 Standards for the Use or Disposal of Sewage Sludge; Final Rule 1993), consists of distributing liquid, dried, or composted sludge on or just below the soil surface where it is employed as a fertilizer or soil conditioner. For example, beneficial uses may include improving tree growth for hardwood reforestation, increasing organic matter and enhancing soil tilth for hay production or growth of native species, or helping to restore disturbed areas by providing nutrients for new plantings.

Land application as practiced by the city of Oak Ridge on the ORR currently involves spraying liquid sludge (2 to 3% solids) under pressure from a tanker, resulting in a thin layer of sludge on the soil surface and vegetation. In addition to the high-pressure surface spray, sludge can also be applied by the same application vehicle using spray nozzles at the rear of the vehicle. Dewatered (or solid) sludge can be applied using manure spreading equipment. Sludge has been applied to approved sites (see Appendix E) at a rate of up to 9.9 metric tons/ha/year (4.4 tons/acre/year), which is below the TDEC permitted rate of 11 metric tons/ha/year (5 tons/acre/year). *(All weights are given on a dry-weight basis.)* DOE has maintained a conservative approach to sludge land application on the ORR. Historically, the city, at DOE's direction, limited the maximum lifetime application to 34 metric tons/ha (15 tons/acre) (Stephenson 1994c). Recently, DOE approved a loading limit of 48 metric tons/ha (22 tons/acre) (DOE 1994c).

There are six active land application sites totaling 71 ha (175 acres) on the ORR (Table 1.1 and Fig. 1.1). Three previously utilized sites totaling 21 ha (52 acres) are currently inactive (Table 1.1). Sludge application on one of these sites, the McCoy site, was stopped because of higher than anticipated levels of cobalt-60 and cesium-137 in the sludge that was applied but not because of reaching radionuclide loading limits.

As DOE land loading limits of 48 metric tons/ha (22 tons/acre) are reached and currently active sites are phased out of use, new sites may be identified for use in the program (See Appendix E for site selection criteria.) and/or the higher, state regulatory loading limit of 110 metric tons/ha (50 tons/acre) may be applied to active and previously utilized sites on the ORR. Before new sites are included in the program, additional NEPA review would be completed.

Prior to April 1993, sludge from ORNL's sewage treatment plant was buried in unlined trenches at Solid Waste Storage Area 6 (SWSA-6) (Bell 1994). This method of disposal was discontinued as of April 1993 at the request of TDEC because the burial ground does not satisfy current regulations for waste management. From April 1993 until December 1993, the sludge was disposed of as fill material in the waste disposal silos at SWSA-6 until TDEC and DOE discontinued this waste disposal option at SWSA-6 (Bell 1994).

Table 1.2 presents a comparison of the current operational information for wastewater treatment and sludge production for ORNL, the K-25 Site, and the city of Oak Ridge POTW. The city of Oak Ridge currently trucks 2 to 6 loads/day (40 to 120 loads/month) of sewage sludge in the city-owned 20,400-L (5400-gal) tanker truck to the active land application sites. On the ORR, the sludge is transferred to a 5300-L (1400-gal) field vehicle for surface spray application (DOE 1994b).

Currently at ORNL, the sludge from treated sewage is being centrifuged, heat-dried on site, and placed in B-25 boxes. A B-25 box is a welded steel container about 1.8 m × 1.2 m × 1.2 m (6 ft × 4 ft × 4 ft), with a capacity of ~2.7 m^3 (96 ft^3). The drying process reduces the volume of liquid sludge by a factor of 70:1 and reduces the moisture content of the sludge to <30% to meet waste acceptance criteria for the low-level Interim Waste Management Facility (IWMF) on the ORR, where the dried sludge is disposed. TDEC has exempted the thermal dryer from additional air permit requirements. Costs for thermal drying of the sludge are $0.66/L ($2.50/gal) of sludge taken from the digester. These costs are in addition to the low-level waste disposal costs of ~$3000/$m^3$ ($85/$ft^3$), which represent an incomplete cost figure that does not include facility closure, inspections, permitting, and other related waste management costs (Bell

1994).

At the K-25 Site, the sludge from treated sewage is currently being dried (20 to 30% moisture remaining) in drying beds for up to 2 years. It is then transferred to B-25 boxes and placed on a storage pad at the K-25 Site (K-1066 H), at an estimated cost of ~$500 per B-25 box (Bowman 1994) and additional storage costs of ~$700/year.

Table 1.1. Sewage sludge land application sites on the ORR

Site name	Total acres on site	Site status
Watson Road	40	Active
Cottonwoods	17	Inactive
Site #8	12	Inactive
Rogers	20	Active
Hayfield #1	25	Active
Hayfield #2	20	Active
Scarboro Road	45	Active
High Pasture	25	Active
McCoy	23	Inactive

Any actions by DOE to manage sludge must conform to federal and state laws and DOE regulations (see Chap. 6). Ideally, any sludge management option would also have the following characteristics: sufficient capacity, economic efficiency, long-term viability, and environmental acceptability (Powlesland 1991). Sewage sludge typically contains both natural and human-made radionuclides. Because there are currently no applicable federal sludge radioactivity standards, the state, the city of Oak Ridge, and DOE established conservative radionuclide limits for ORR sludge application (Stephenson 1994b). These limits require that the resulting average concentration of uranium and other radionuclides with longer decay periods in the receiving soil will not generally exceed two times background (Hibbitts 1989). In addition, to ensure long-term acceptability of the Oak Ridge sludge application program, the city has proposed, and TDEC has approved, use of a risk-based model [Residual Radioactivity computer model (RESRAD)] for determining acceptable radionuclide concentrations in sludge for application on the ORR (Gilbert et al. 1989; Stetar 1993). Attachment A to Appendix D summarizes this methodology for establishing dose-based radionuclide limits for the land application program, and Tables 1.2 and Table 1 of Attachment A compare the radionuclide limits in sludge and in soil using the current 2× criterion with the limits calculated using the RESRAD model, based on conservative assumptions.

Table 1.2. ORNL, K-25 Site, and city of Oak Ridge sanitary sludges

Activity	ORNL	K-25 Site	City of Oak Ridge POTW
Building number	2521	K-1203	South of Oak Ridge Turnpike at Anderson-Roane County Line

Avg. wastewater treatment facility flow rate	1.1 million L/day (300,000 gal/day)	0.9 million L/day (250,000 gal/day)	19.7 million L/day (5.2 million gal/day)
Design treatment facility flow rate	1.1 million L/day (300,000 gal/day)	2.2 million L/day (600,000 gal/day)	22.2 million L/day (5.87 million gal/day)
Treatment facility maximum surge rate	3.8 million L/day (1,000,000 gal/day)	3.8 million L/day (1,000,000 gal/day)	41.8 million L/day (11 million gal/day)
Treatment facility design	48 hour aeration	48 hour aeration	Extended aeration
Sludge treatment process	Aerobic digestion	Aerobic digestion	Anaerobic digestion
Sludge retention time	15 days	51 Hours	30 days
Sludge treatment temperature	22-23 C (Summer) 12-13 C (Winter)	26 C (Summer) 13 C (Winter)	35 C
503 Vector attraction reduction method	None Met[a]	38% volatile solids reduction	38% volatile solids reduction
Avg. % solids of generated sludge	2-4%	2-4%	2-4%
Avg. gallons of sludge generated per year	200,000	48,000	3,600,000

Amount of sludge generated per year (dry wt)	19 tons (short) 17,272 kg	8 tons (short) 7,264 kg	400 tons (short) 363,636 kg
503 A/B classification	A (due to thermal drying); no classification without drying or additional treatment[b]	B	B
Major line items planned	Laundry water separation tank to reduce amount of radionuclides entering sanitary sludge; near completion at end of March 1996.	None planned	Dewatering capabilities to be added to increase cost effectiveness. Belt press to be installed at city POTW in late 1997, early 1998.

[a]Can meet 40 *CFR* 503 vector attraction reduction requirements by satisfying one of the requirements listed in 503.33(b)(1) through (b)(10). See Appendix G for an explanation of these requirements.
[b]Can meet 40 *CFR* 503 (Standards for the Use or Disposal of Sewage Sludge 1993) Class B pathogen reduction requirements by satisfying one of the requirements listed in 503.32(b)(2) through (b)(4). See Appendix G for an explanation of these requirements.

A major benefit of land application, when practiced according to EPA guidelines, is that exposing pathogens* remaining in the sludge to desiccation* and sunlight significantly reduces their survival (EPA 1989). Sludge application is prohibited during precipitation events or when the ground is frozen because moisture and cold temperatures contribute to pathogen survival, and runoff during rain events might carry pathogens, nitrates, phosphates, and other sludge constituents to surface water.

ORNL and K-25 Site sewage sludges have been characterized to determine their compatibility with the city's industrial sewage pretreatment program and their capability to meet industrial discharge standards set by the city. Any sewage sludge from ORNL and the K-25 Site added to the Oak Ridge POTW and subsequently included in the sludge land application program would have to meet the same pretreatment standards as do other industrial users of the Oak Ridge POTW.

1.3 SCOPE OF THE ANALYSIS

This environmental assessment (EA) evaluates the impacts (1) from raising current, DOE self-imposed land loading limits of 48 metric tons/ha (22 tons/acre) to the TDEC-permitted value of 110 metric tons/ha (50 tons/acre), increasing radionuclide loading above the conservative 2× level to dose-based RESRAD limits, and adding ORNL and K-25 Site sludges to the existing land application program; (2) from no action; (3) from developing an independent DOE sludge application program of ORNL and K-25 Site sewage sludges in conjunction with continuing sewage sludge land application on the ORR by the city of Oak Ridge; and (4) from DOE applying ORNL and K-25 Site sewage sludge on active and previously utilized sites on the ORR and discontinuing the city of Oak Ridge's sludge land application on the ORR. Other alternatives for management of the sewage sludge, including composting, shallow land burial, incineration, and off-site disposal, are considered but for the various reasons specified are not evaluated further in this EA.

This EA conforms to the requirements of the Council on Environmental Quality (CEQ) regulations (40 *CFR* Parts

1500-1508) implementing the National Environmental Policy Act of 1969 (NEPA) and DOE NEPA Implementing Procedures (10 *CFR* 1021).

A "sliding-scale" approach is the basis for analysis of impacts of the proposed action and alternatives. That is, certain aspects of the action have a greater potential for causing adverse environmental impacts; therefore, they are discussed in greater detail in this EA than those aspects with little potential for impact.

Public involvement is important to the NEPA process. Prior to preparation of this EA, public input was requested at DOE's July 12, 1994, Availability Session. Posters, informational handouts, a videotape, and resource personnel were available to explain the sludge land application program and potential program changes. No concerns were expressed about the land application program, either at the meeting or in the written comments and letters received from stakeholders. On December 27, 1995, DOE published a Notice of Intent to prepare an EA. This notice included names of individuals to contact with comments or requests for copies of the EA. To date, no comments or requests have been received.

DOE is committed to the complete assessment and full disclosure of the environmental consequences of its proposed actions. If potentially significant environmental impacts are found to be associated with the continuation of the city of Oak Ridge's sewage sludge land application and addition of ORNL and K-25 Site sewage sludge to the land application program, an environmental impact statement will be prepared; if not, DOE will issue a Finding of No Significant Impact and proceed with the proposed action.

2. DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES

2.1 PROPOSED ACTION

2.1.1 Raising Land Loading Limits to the TDEC Permitted Level, Increasing Radionuclide Loading Above the Conservative Twice Background (2x) Level to RESRAD Limits, and Adding ORNL and K-25 Site Sludges to the Sludge Land Application Program

DOE proposes to raise the sludge land application loading limits from the current, self-imposed conservative 48 metric tons/ha (22 tons/acre) lifetime loading to the TDEC-permitted level of 110 metric tons/ha (50 tons/acre). Increasing the lifetime loading limits of sludge solids would not change other applicable limits, such as those for heavy metals and the land application rate of 11 metric tons/ha/year (5 tons/acre/year). Ceiling concentration limits for heavy metals in sludge and cumulative loading limits for the total quantity of heavy metals applied over the life of a site would still have to be met. Likewise, all TDEC guidelines restricting sludge application under specific site conditions would still apply.

In addition, DOE proposes increasing radionuclide loading above the conservative 2× level to dose-based RESRAD limits. As explained in Sect. 1.2, the sludge land application program is currently operating under an agreement that restricts the average concentration of uranium and other long-lived radionuclides such as cesium-137 in the upper 15 cm (6 in.) of the receiving soil to 2× the background concentration in the existing (or baseline) soils. This limit is very conservative when compared with dose limits mandated by the EPA (DOE 1995). The city of Oak Ridge has proposed, and TDEC has accepted, a methodology for establishing dose-based radionuclide limits using the RESRAD model. Attachment A to Appendix D in this EA explains the methodology for deriving dose-based soil limits and equivalent radionuclide limits in sludge. Table 1 of Attachment A summarizes the applicable calculated dose-based limits. The limit of each radionuclide corresponds to a 4 mrem/year dose limit to the maximally exposed individual. If the sludge land application program were to adopt the calculated dose-based limits using a sum-of-fractions methodology, substantially more sludge per hectare (acre) could be applied on active and previously utilized sites, up to the state-approved limit of 110 metric tons/ha (50 tons/acre) (DOE 1995).

DOE also proposes to add ORNL and K-25 Site sanitary wastewater treament plant sludge to the existing sewage sludge land application program on the ORR. This would add ORNL and the K-25 Site as industrial customers of the city of Oak Ridge sewage treatment plant. ORNL and the K-25 Site would be subject to prescribed sanitary discharge limits and restrictions similar to those of the existing Y-12 Plant and other industrial sewage generators located in the city. Appendix B contains a copy of the existing Y-12 Plant industrial discharge permit. The industrial discharge permit is designed to ensure that the total contaminant loading from all industrial customers allows Oak Ridge's POTW to meet its National Pollutant Discharge Elimination System (NPDES) permit limits.

Sludge would be transported by truck from ORNL and the K-25 Site to the city's POTW, which would result in ~3 to 4 additional vehicle trips per month (increase of 4 to 5%). A tanker truck [e.g., a 20,400-L (5400-gal) capacity tanker] would transport sludge from ORNL about every 2 weeks and from K-25, once a month. At K-25 and ORNL, a loading station, similar to the one at the POTW, would be built for loading the tanker truck. Costs for the loading station are estimated at $15,000 to $30,000 for ORNL (Bell 1994) and ~$30,000 for the K-25 Site (Bowman 1994). Each tanker loading station would consist of an overhead sludge delivery pipe and support boom, a concrete pad (roughly 40 × 20 ft) sloped to a drain, a sump for the drain, and a pipe system to return any spillage to the treatment stream. The slope configuration of the pad would be designed to contain any sludge that might spill. Spillage would flow to a collection sump by way of a drain, where it would be contained and then be pumped back into the treatment system through the associated piping. The drain could be kept covered except during loading operations to prevent the unwanted collection of precipitation. Loading could be conducted during dry weather, or during wet weather for transport to the Oak Ridge POTW if the sump pump were used.

After transport to the city's POTW, the sewage sludge would enter the plant at an initial stage of the treatment stream. The city's POTW has sufficient capacity for this addition to its influent. Although K-25 Site sewage sludge currently meets Class B standards and could be applied directly without additional treatment, logistical convenience and the relatively small quantity of K-25 Site sludge make it likely the sludge would be introduced at an initial stage; however, the decision on how to add the sludge to the city's treatment plant would be made by the city of Oak Ridge POTW as circumstances dictate. ORNL sludge would require additional monitoring and/or treatment prior to land application. Input of ORNL sludge to the city's POTW treatment process would satisfy this requirement.

Sewage sludge from the city's POTW would be applied at approved sites (see Appendix E) on the ORR at the TDEC-permitted land loading rate of 11 metric tons/ha/year (5 tons/acre/year) for up to 10 years [i.e., a total of 110 metric tons/ha (50 tons/acre)]. The sewage sludge would continue to be applied at currently active sites as well as at previously utilized, currently inactive sites on the ORR. Active and inactive sites are identified in Table 1.1, with their locations shown on Fig. 1.1.

Prior to transport to the POTW, sludge would be sampled and analyzed for constituents of concern to meet the Industrial Discharge Permit limits issued to ORNL and the K-25 Site. These analytes would be defined in the city's NPDES Sludge Management Plan and would be similar to those specified in the city's land application approval (LAA) letter (Appendix A) and the inorganic and organic constituent samples required by the city's NPDES permit (Tables 2.1 and 2.4, respectively). To verify that ORNL and the K-25 Site sewage sludge meets the city of Oak Ridge's waste acceptance criteria for industrial users, a baseline analysis would be required for the 129 constituents of concern listed in 40 *CFR* 261, Appendix IX. The cost of completing the baseline analyses is estimated to be ~$25,000 - $30,000. However, NPDES-mandated analyses would be required regardless of the sludge management option selected (Bell 1994).

Adding ORNL and the K-25 Site to the ongoing land application program would benefit both DOE and the city of Oak Ridge. DOE's sewage sludge would be managed efficiently and cost effectively by the city's existing program, and DOE would benefit from biosolids recycling. The city would continue to have sites for beneficial reuse of sludge on DOE property, which has restricted access and extensive monitoring capability.

2.1.2 Sludge Characterization

This section discusses the characterization of the sludges from the city of Oak Ridge POTW, which are currently being land applied on the ORR, and the sludges from ORNL and the K-25 Site, which are proposed for addition to the sludge land application program. Sludge characteristics discussed include constituent inorganic chemicals, heavy metals, organic chemicals, radionuclides, and pathogens as they relate to sludge Classes A and B.

Table 2.1. Inorganic parameters and levels of inorganic constituents in city of Oak Ridge POTW sewage sludge (1993-1995)

		1993 levels (mg/kg dry wt)			1994 levels (mg/kg dry wt)			1995 levels(mg/kg dry wt)		
Analyte	Sampling frequency	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Ammonia-nitrogen[a]	Monthly	20,300	31,458	60,000	16,500	24,408	30,000	5,900	27,908	34,900
Manganese	Monthly	1,260	1,260	1,260	1,290	1,454	1,710	854	1,227	1,540
Nitrate nitrogen[a]	Monthly	8.5	19.3	40.2	1.4	56.48	269.0	0.1	21.6	144.0
Nitrite nitrogen[a]	Monthly	6.5	7.66	8.8	1.4	11.05	30.7	0.1	3.5	30.7
Organic nitrogen	Monthly	31,000	35,500	40,000	13,700	37,716	49,800	3,550	39,279	66,000
pH	Daily	7.1	7.33	7.7	7.0	7.4	8.1	7.1	7.33	7.5
Potassium	Monthly	3,420	4,495	5,960	3,180	4,620	5,410	2,690	4,239	6,020
Phosphorus	Monthly	25,400	31,033	36,200	28,000	31,400	36,800	23,200	30,400	36,800
Total Kjeldahl nitrogen[a]	Monthly	59,200	71,833	94,100	34,600	62,675	77,200	32,700	67,600	89,100
Total nitrogen[b]	Monthly	61,616	71,852	94,111	34,605	62,731	77,223	32,700	67,621	89,127
Total solids %	Daily	2.0	2.8	3.2	2.5	2.9	3.3	2.5	2.9	3.3
Volatile solids (% of TS)	Daily	61%	63%	63%	58%	60%	62%	60%	62%	63%

Source: City of Oak Ridge 1994, 1995, and 1996.

[a] These parameters are required to be sampled annually by NPDES permit #TN0024155. Reporting of quantitative data is required, but limits are not specified.

[b] Total nitrogen represents the sum of total Kjeldahl and nitrate nitrogen.

Table 2.2. Concentrations of heavy metal constituents in city of Oak Ridge POTW sewage sludge (1993 - 1995) versus 40 CFR 503.13 ceiling concentration limits

Heavy metal	40 *CFR* 503.13 ceiling conc. limits	1993 levels (mg/kg dry wt) Min	Mean	Max	1994 levels (mg/kg dry wt) Min	Mean	Max	1995 levels (mg/kg dry wt) Min	Mean	Max
Arsenic	75	3.2	5.9	25.1	2.2	4.2	9.1	1.1	9.03	9.12
Cadmium	85	8.4	10.4	15.1	4.7	9.4	17.8	4.9	8.3	11.0
Copper	4,300	210.0	460.1	544.0	411.0	450.6	490.0	413.0	476.5	543.0

Lead	840	47.4	69.3	88.4	81.5	103.6	128.0	46.0	71.2	116.0
Mercury	57	5.7	9.12	16.2	3.9	7.59	9.45	4.5	57.6[a]	264[a]
Molybdenum	75	20.0	27.8	33.8	16.3	19.73	23.5	7.0	17.7	26.6
Nickel	420	31.6	40.2	51.0	15.9	37.6	45.6	24.3	35.8	61.5
Selenium	100	3.6	7.6	20.9	1.0	5.7	10.2	2.6	6.5	15.1
Zinc	7,500	1,390	1,698	2,070	1,540	1,700	1,840	1,390	1,641	1,940

Source: City of Oak Ridge 1994, 1995, and 1996.

[a] Sludge that exhibits mercury levels in excess of the 40 *CFR* 503.13 limits will be disposed of in a properly permitted landfill under a special waste permit from TDEC, Solid Waste Division.

Table 2.3. Concentrations of heavy metal constituents in K-25 Site and ORNL sewage sludges

Heavy metal	K-25 Site(mg/kg dry wt)	ORNL(mg/kg dry wt)	40 *CFR* 503.13ceiling concentration limits (mg/kg dry wt)
Arsenic	*	13	75
Cadmium	*	4.3	85
Chromium	*	29	++
Copper	*	*	4,300
Lead	*	48	840
Mercury	*	26	57
Molybdenum	*	*	75
Nickel	*	*	420
Selenium	*	17	100
Zinc	*	*	7,500

*Indicates not sampled for total metals.

++ This limit has been excised by the EPA.

Table 2.4. NPDES organic parameters and concentrations of organic constituents in city of Oak Ridge sewage sludge (1993-1995)

		1993 levels (mg/kg dry wt)			1994 levels (mg/kg dry wt)			1995 levels (mg/kg dry wt)		
Analyte	Sampling frequency	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Aldrin	Semiannually	BMDL	—	BMDL	BMDL	0.55	1.1	BMDL	0.011	0.021
Chlordane	Semiannually	BMDL	0.26	0.55	BMDL	—	BMDL	BMDL	0.16	0.33
DDD	Semiannually	BMDL	—	BMDL	BMDL	—	BMDL	BMDL	—	BMDL
DDE	Semiannually	BMDL	—	BMDL	BMDL	0.025	0.05	BMDL	—	BMDL
DDT	Semiannually	BMDL	—	BMDL	BMDL	—	BMDL	BMDL	—	BMDL
Dieldrin	Semiannually	BMDL	—	BMDL	BMDL	0.035	0.07	0.083	0.088	0.09

Heptachlor	Semiannually	BMDL	—	BMDL	BMDL	—	BMDL	BMDL	—	BMDL
Lindane (gamma-BHC)	Semiannually	BMDL	—	BMDL	BMDL	—	BMDL	BMDL	.00375	.0075
PCBs	Semiannually	BMDL	—	BMDL	BMDL	0.48	0.96	BMDL	0.19	0.37
Toxaphene	Semiannually	BMDL	—	BMDL	BMDL	—	BMDL	BMDL	—	BMDL
Trichloroethene	Semiannually	U	—	U	U	—	U	U	—	U
Benzo(a)pyrene	Semiannually	U	—	U	U	—	U	U	—	U
Dimethylnitrosamine (n-nitroso-di-methylamine)	Semiannually	U	—	U	U	—	U	U	—	U
Hexachlorobenzene	Semiannually	U	—	U	U	—	U	U	—	U
Hexachlorobutadiene	Semiannually	U	—	U	U	—	U	U	—	U

Source: City of Oak Ridge 1994, 1995, and 1996.
BMDL = Below method detection level.
U = Undetected. Indicates that the compound was analyzed for but was not detected.

Inorganic Chemicals

Sludge inorganic analytical parameters must be sampled annually, as stated in the LAA issued to the city of Oak Ridge by the state of Tennessee (Appendix A). The city performs these analyses daily or monthly. Table 2.1 shows the minimum, mean, and maximum levels of each required analyte found in the city's sludge in 1993, 1994, and 1995 (City of Oak Ridge 1994, 1995, 1996).

Heavy Metals

Anaerobically* digested sludge applied to the ORR is sampled monthly although 40 *CFR* 503 regulations for the land application of sludge require only quarterly sampling. With the exception of the recent Y-12 mercury incident, the concentrations of heavy metals have been well below the 40 *CFR* 503.13 ceiling concentration limits. Table 2.2 compares the minimum, mean, and maximum concentration of each heavy metal in Oak Ridge POTW sludge with the ceiling concentration limits for that metal (City of Oak Ridge 1994), and Table 2.3 shows concentrations of heavy metals in K-25 Site and ORNL sludges. Concentrations of heavy metals in the sludge stream are monitored periodically (DOE 1995). This monitoring can help to prevent an abnormally high concentration of a heavy metal from being applied on the ORR, or it can be used to prevent total loading limits from being exceeded. A recent incident, outlined in Appendix F, involving higher than normal concentrations of mercury in the waste stream to the Oak Ridge POTW is an example of the effectiveness of monitoring within the sludge land application program.

Organic Chemicals

The city of Oak Ridge's NPDES permit requires annual sampling of sludge organic analytical parameters. Currently, the city performs a semiannual organic analysis of the sludge. Table 2.4 summarizes the levels of organics in the sludge in 1993, 1994, and 1995. Most of the organic chemicals were either undetected or below the detection level of the method.

Radionuclides

Although there are no federal requirements to test sludge for radionuclides or federal limits on the radiological content of sludge other than the TDEC Division of Radiological Health license conditions governing sewage dischargesto POTWs from licensees or DOE Order 5400.5 for DOE-owned facilities, both the sludge and the land application areas on the ORR are part of an ongoing monitoring program (see Chap. 6 for a summary of permit and regulatory requirements). Because of the various contributions of natural background radiation, atmospheric deposition, industrial operations, and medical facilities, all sludges contain radioactive materials. The radiological content of municipal sludges in general is of concern to the Nuclear Regulatory Commission and EPA; however, few programs in the United States analyze radiological content in sludge (GAO 1994). Bulk gamma and selected radionuclides (cobalt-60, cesium-137, iodine-131) are monitored by the Oak Ridge POTW daily during application, analyzed weekly using composite sludge samples, and monitored annually in land application area soils. The city of Oak Ridge collects the soil samples and pays ORNL to analyze the samples.

In 1984, there was a report of elevated levels of cesium-134, cesium-137, cobalt-60, and manganese-54 in the sludges from the Oak Ridge POTW; however, no cleanup was necessary at the treatment plant (GAO 1994). It was determined that land-applied sludge contained elevated levels of cobalt-60 from the Quadrex facility in Oak Ridge. Because of the relatively short half-life of cobalt-60 (5.3 years), the levels were determined to be of minimal risk. However, the land application site (McCoy) was closed, and an extensive sampling and monitoring program was developed to ensure that no sludge with radioactivity in excess of prescribed action levels outlined in the Oak Ridge POTW Gamma Screening Protocol would be applied without additional sample screening by ORNL and approval from DOE and the state (Birchfield 1994). Low-level radiation surveys were conducted at the McCoy site in September 1994, and active and retired sludge application sites were also surveyed. Radiation above background levels could not be detected (Mlekodaj 1994).

Table 2.5 shows the average radiological characterization of the Oak Ridge sewage sludge from 1988 to 1993, and Table 2.6 summarizes the mean and maximum radionuclide levels in the city of Oak Ridge POTW sludge in 1993. Table 2.7 shows the mean values from radiological sampling of ORNL sewage treatment plant sludge for 1992 and 1993. Table 2.8 shows the radiological content of K-25 Site sludge, which was analyzed in January 1996.

Major contributors to the radiological content of the city of Oak Ridge POTW sludge include residential customers contributing naturally occurring radionuclides (radium, uranium, potassium-40, beryllium-7), medical facilities (iodine-131, technetium-99), industrial facilities (cobalt-60 and cesium-137), and the Y-12 Plant (uranium). As expected, the levels of naturally occurring radionuclides in the sludge remain relatively constant. Radionuclides in sludge originating from medical facilities have increased approximately sixfold in the past 5 years. Current 10 *CFR* 20 requirements exclude from regulation patient excreta, which may contain radioactive materials as a result of nuclear medical procedures (Stephenson 1994a). The contribution of radionuclides from industrial facilities (including the Y-12 Plant) has fallen dramatically in the past 5 years (Table 2.5). For example, the uranium content of sludge dropped tenfold between 1988 and 1993 (from 140 pCi/g to 13 pCi/g), most likely due to continuing improvements in waste disposal procedures at the Y-12 Plant. With the exception of iodine (131I) used in medical procedures, this overall downward trend is expected to continue.

Risk-based radionuclide limits for sludge (see Attachment A to Appendix D) were developed for use by the city of Oak Ridge for the land application program using the RESRAD computer code (Gilbert et al. 1989; Stetar 1993) and very conservative risk assumptions [i.e., residential farmer and pica (soil-eating) child receptors]; this methodology was accepted by TDEC. Attachment A to Appendix D of this EA explains how risk-based radionuclide limits were calculated to be protective of human health at a maximum dose of 4 mrem/year to the most exposed individual, assuming sludge application at a rate of 5 tons/acre/year for up to 10 years (equaling 50 tons/acre lifetime loading). The Attachment also explains that the assumption of a farm family moving onto the sludge application site immediately following the final sludge application is overly conservative because of application site restrictions that would prohibit such action. Proposed radionuclide levels in sludge were derived from the soil limits calculated using the protective 4 mrem/year dose.

Pathogens

The pathogen reduction requirements for sewage sludge are divided into two categories: Class A and Class B. Appendix G of this EA provides a brief summary of 40 *CFR* 503, Subpart D, Pathogen Standards and Treatment Processes. If the sewage sludge meets Class A, pathogen levels are reduced to levels below detection limits. If the sewage sludge meets Class B, the pathogen levels are reduced to levels that are unlikely to threaten public health and the environment when applied to land with specific use restrictions. The site restrictions for application of Class B sludge minimize the potential for human and animal contact until environmental attenuation has further reduced the pathogen levels. Sewage sludge that is applied to home gardens or distributed in small quantities to the public must meet Class A pathogen requirements. Sewage sludge that is applied in bulk form to agricultural land, forest, reclamation sites, or public sites must meet either Class A or Class B pathogen requirements.

Table 2.5. Historical radiological characterization of Oak Ridge sanitary sewage sludge (selected radionuclides)

Radionuclide	Half-life	Average concentration, pCi/g dry weight 1988	1989	1990	1991	1992	1993
Beryllium-7	53.6 days	1.2	1.5	1.7	1.6	1.3	1.7
Potassium-40	1.28×10^9 years	7.0	6.8	7.2	5.9	5.1	5.8
Cobalt-60	5.27 years	5.3	2.5	3.3	0.9	0.8	0.6
Iodine-131	8.04 days	6.8	8.5	5.9	9.7	17	42
Cesium-137	30.2 years	2.0	1.3	2.7	1.4	0.5	0.6
Radium-228	5.8 years	0.6	0.9	1.2	0.7	0.7	0.9
Uranium - total	4.5×10^9 years	140	50	30	25	23	13[a]
235Uranium assay		0.32%	0.51%	0.71%	0.80%	0.90%	0.8%[b]

Source: Adapted from Stephenson 1994d.

[a] Based on gamma spectroscopy; prior year total uranium by neutron activation, ^{235}U assay by mass spectroscopy.

[b] Sources of radionuclides in sewage sludge include naturally occurring radionuclides, medical radionuclides (iodine-131), radionuclides from atmospheric deposition, and nuclear facilities with state-permitted radionuclide discharges.

Table 2.6. Mean and maximum radionuclide levels (pCi/g dry weight) in the city of Oak Ridge POTW sludge (1993)

Radionuclide	Mean level	Maximum level
Cobalt-60	0.64	1.21
Cesium-137	0.69	1.55
Iodine-131	44.81	180.72
Beryllium-7	1.83	3.67
Potassium-40	6.13	12.85
Radium-228	0.92	1.43
Uranium-235	0.73	2.40
Uranium-238	14.03	33.74

Table 2.7. ORNL sewage treatment plantdrying bed sludgeradiological sampling results (pCi/g dry wt) for 1992 - 1993

Radionuclide	Mean
Cobalt-60	3.0
Cesium-137	6.1
Europium-152	2.4
Europium-154	5.4

Europium-155	1.2
G-alpha	47.1
G-beta	833.7
Potassium-40	6.8

Table 2.8. K-25 Site Analytical Services Organizationsludge radiological results (pCi/g dry wt) analyzed January 30, 1996

Radionuclides	Result (pCi/g dry wt)	± Error (pCi/g dry wt)
Plutonium-238	1.14	1.4
Plutonium-239	0	1.6
Technetium-99	.248	.12
Americium	.409	.67
Neptunium-237	0	.85
Thorium-228	.146	.41
Thorium-230	.104	3.5
Thorium-232	1.17	1.2
Cesium-137	0	2.9
Protactinium-234m	.0245	.053
Thorium-234	2.59	.30
Uranium-235	1.18	3.0

The city of Oak Ridge POTW sludge and K-25 Site sludge meet Class B standards (Table 1.2). Under the thermal treatment program, ORNL sludge is Class A; however, the sludge considered for addition to the sludge land application program is not classified because thermal treatment would be discontinued. Following additional treatment at the city's POTW, the ORNL sludge would be Class B.

Either liquid or solid sludge that meets either Class A or Class B standards may be land applied on the ORR under the proposed action. The city of Oak Ridge POTW is currently producing and applying liquid Class B sludge. For that reason, liquid Class B sludge is assumed for purposes of analysis in this EA. However, solid (dewatered) Class B and liquid or solid Class A sludges may be land applied anywhere liquid Class B application is permissible.

Class B sludge is well suited for land application on the ORR because the existing access restrictions are consistent with site restrictions for bulk sludge land application. Class A sludge has fewer restrictions about how and where it can be applied, but there are higher costs for additional treatment to meet Class A standards (e.g., processes to further reduce pathogens, explained in Appendix G).

2.2 NO ACTION

The no-action alternative provides an environmental baseline with which impacts of the proposed action and alternatives can be compared. Under the no-action alternative, ORNL and K-25 Site sewage sludge would not be transferred to the city of Oak Ridge POTW. Sewage sludge management for these two facilities would continue as currently practiced [i.e., sewage sludge dewatering, air drying (K-25 Site only) or thermal drying (ORNL only), and disposal or storage in B-25 boxes]. The city of Oak Ridge would continue to apply sewage sludge on active and previously utilized sites until the current DOE loading limit of 48 metric tons/ha (22 tons/acre) is reached at these sites, and the Y-12 Plant would continue to discharge sewage directly to the Oak Ridge POTW. The city would be required to select some other sludge management methods [e.g., alternative (non-ORR) land application sites]. This would result in non-federal activities that are beyond the scope of this EA.

2.3 DOE PROGRAM FOR LAND APPLICATION OF ORNL AND K-25 SLUDGE

This alternative would combine the continuation of sewage sludge land application by the city of Oak Ridge on the ORR and the initiation of an independent DOE application program for ORNL and K-25 Site sewage sludges. Application within both programs would continue on active and previously utilized land application sites on the ORR. LAA letters would be required for independent DOE application.

Sewage sludge would be trucked [~3 to 4 truckloads per month using a 20,400-L (5400-gal) tanker truck] from ORNL and the K-25 Site directly to the application sites. A single tanker truck would service both facilities. Both facilities would be required to construct a tanker loading station, as described in Sect. 2.1.1, for loading the tanker truck. A DOE program also would require the purchase, lease, or contracting of a field sludge application vehicle. Sludge would be applied at approved sites on the ORR at the TDEC-permitted land loading rate of 11 metric tons/ha/year (5 tons acre/year) for up to 10 years [i.e., a total of 110 metric tons/ha (50 tons/acre)].

Sampling and analysis requirements would be the same as those for the proposed action except that both entities applying sludge (DOE and the city of Oak Ridge) would have sampling, analysis, and reporting requirements consistent with their LAAs from TDEC.

DOE's sewage sludge program necessarily would be coordinated with the city's existing program in order to stay within land loading limits. This coordination could be as simple as dedicating specific application sites (or portions of sites) to each program. If certain sites were dedicated to DOE use only, DOE could be assured of a long program life because of its smaller volume of sludge. The city would continue to have sites for beneficial reuse of sludge on DOE property, which has the benefits of restricted access and extensive monitoring capability, until loading limits were reached.

2.4 DEVELOPMENT OF DOE SLUDGE APPLICATION PROGRAM AND DISCONTINUATION OF CITY'S SLUDGE APPLICATION ON THE ORR

Within this alternative, the development of an independent DOE sludge land application program for the beneficial use of ORNL and K-25 Site sewage sludges would coincide with the discontinuation of the city of Oak Ridge's sewage sludge application on the ORR. DOE's land application program would continue to use active and previously utilized application sites on the ORR, while the city's program would be required to obtain application sites off the ORR or use an alternative sludge management method. Implementation of this alternative would involve the same requirements of DOE as the independent sludge land application programs alternative [i.e., construction of tanker loading stations, sludge transportation, sludge application, and satisfaction of regulatory (LAA letters) and sampling, analysis, and reporting requirements].

2.5 ALTERNATIVES CONSIDERED AND ELIMINATED FROM FURTHER CONSIDERATION

2.5.1 Composting of ORNL and K-25 Site Sludge

Compost is a useful land application product with fertilizer and soil amendment value, and it is categorized as a beneficial use under 40 *CFR* 503. Composting sludge and yard waste is becoming a standard practice in some areas (Outwater 1994). The most common problem, odor control, would probably be of minor concern on the ORR because of the distance to nearby residents. Composting processes include static pile composting (preferably aerated* static pile composting), windrow systems, and in-vessel systems. Typically, dewatered sludge is mixed with a bulking agent, such as wood chips, which acts as a carbon source. A pile of the sludge/amendment mixture is constructed that allows composting into humus in a few weeks (static pile composting), perhaps with air blown through the piles (aerated static pile composting). Windrow composting involves arranging the piles in long rows that are turned a few times each week. In-vessel composting is highly mechanized, occurs within a specialized vessel, and provides the most completely aerobic composting environment (Outwater 1994). Each process has its advantages and disadvantages; costs are much lower for aerated static pile and windrow systems than for in-vessel systems, which have a high capital cost. [Sevier County, Tennessee, has an in-vessel system, which was developed at an initial cost of $6.5 million and has a current annual operating cost of $900,000 (Anonymous 1993)]. The potential availability of bulking agents produced at the three plants on the ORR (food wastes, paper not suitable for recycling, bedding waste from the "mouse house" at the Y-12 Plant, brush from logging operations), combined with leaves and other yard wastes collected from Oak Ridge residents, would make composting a reasonable long-term alternative (Bell 1994).

The extensive planning and coordination required to incorporate composting into a comprehensive waste management program would make this alternative a better choice for long-term sludge management. For example, providing a bulking agent (typically wood chips or yard waste) to mix with dewatered sewage sludge would require coordination and planning throughout DOE's waste management programs and, potentially, with the city of Oak Ridge. Similarly, the long-term investment issues associated with composting (e.g., dedicated land and equipment) would involve actions by the city of Oak Ridge, DOE, and TDEC. The city of Oak Ridge does not currently have a composting program for yard wastes, nor does DOE use composting as part of its waste management strategy at the three plants. Should composting be considered as a long-term sludge and solid waste management option, comprehensive analyses would be needed to define sources of bulking agents, preferred composting method, relative participation by DOE and the city of Oak Ridge, locations for compost application or beneficial use options, etc. In addition, a NEPA review would be required for DOE participation in a composting program.

Composting could be a viable long-term option for sludge management, but the complexity of institutional coordination that would be required to implement an effective composting program precludes composting as an immediate solution to the current need for land application sites and a suitable disposition of ORNL and K-25 Site sludge in the near future. Because composting does not satisfy the purpose and need of the proposed action, it is an alternative whose analysis is beyond the scope of this EA and it will not be considered further.

2.5.2 Shallow Land Burial Alternative

The shallow land burial alternative has already been discontinued at the request of TDEC (see Sect. 1.2) (Bell 1994). To reinstate this alternative would require either a special waste permit for disposal at the Y-12 Plant sanitary landfill or site selection and development of an approved sludge landfill, or sludge-only monofill, a time-consuming and costly process. Land use restrictions for a sludge landfill would be of longer duration than those for land application because of the greater concentration of sludge that would be disposed of in one area. Although well-designed sludge monofills, typically trench or area fills, do not usually have negative environmental impacts, the burial alternative does not provide for beneficial use of the nutrient-rich sludge. Because of the time and cost involved and because there would be no beneficial use of sludge, this is not a preferred alternative and it will not be considered further.

2.5.3 Incineration Alternative

The incineration of sewage sludge is a very costly [$1.80/kg ($4/lb)] and unnecessarily stringent management option for the contamination level in the sludge (Bell 1994). Like shallow land burial, this alternative does not allow beneficial use of the sewage sludge. In addition, the potential air quality impacts of incineration and the waste stream(s) generated from the air pollution control system of the incinerator would be negative impacts. Therefore, this alternative is not preferred and it will not be considered further.

2.5.4 Off-site Disposal Alternative

Off-site disposal of sewage sludge would require meeting the waste acceptance criteria of an approved landfill. Disposing of sewage sludge at an off-site landfill would require special permission from the state and would incur the cost of disposal charged by the landfill. As in the two preceding alternatives, off-site disposal does not allow beneficial use of the sewage sludge and will not be considered further in this EA.

3. DESCRIPTION OF THE AFFECTED ENVIRONMENT

3.1 REGIONAL DEMOGRAPHY/SOCIOECONOMICS

The first step in providing background for demographic* and socioeconomic impact analysis is to define a region of influence for the proposed and alternative actions. All activity related to the alternatives would take place either within the city of Oak Ridge or on the ORR, both of which are located within Anderson and Roane Counties, Tennessee. Although the site of the proposed activities represents a small portion of the entire two-county area, the actions taking place could have repercussions for the whole area's economy. Therefore, it was assumed that Anderson and Roane Counties were the appropriate definition for the region of influence (see Appendix C).

Oak Ridge is located in the east central section of Tennessee, ~32 km (20 miles) west of Knoxville, Tennessee. Oak Ridge includes portions of both Anderson and Roane Counties. There were 27,310 people living in Oak Ridge in 1990, representing 23.6% of the total region of influence population. Appendix C describes the demographics of the area in detail (Table C.1 and Table C.2) and reports summary statistics on housing in Oak Ridge, Anderson, and Roane Counties, the region of influence, and Tennessee (Table C.2 and Table C.3). The total number of housing units has grown over the last decade for both the city and the counties.

Table C.4 and Table C.5 provide a background on employment and the number of building establishments in the region of influence. A total of 71,046 people were employed in the region of influence in 1992. The greatest average annual growth in employment between 1970 and 1992 occurred in the services sector (6.7%), followed by construction (6.4%), agricultural services (5.8%), and transportation and public utilities (3.6%). The two biggest employment declines over the same 22-year period occurred in mining (-5.4%) and manufacturing (-0.5%).

Table C.6 shows the breakdown in average annual earnings per employee by sector. The highest earnings in 1992 were for federal civilian employees ($44,935), followed by manufacturing ($40,611), transportation and public utilities ($31,195), services ($30,024), and wholesale trade ($27,097). Table C.7 shows per capita income trends for the region of influence from 1980 to 1992. Per capita income increased an average annual rate of 6.1% in the region of influence over the dozen years; however, the real rate of increase averaged only 1.5% per year.

3.2 LAND USE

The ORR consists of 13,969 ha (34,516 acres) of federally-owned land, most of which is within the corporate limits of the city of Oak Ridge in Anderson and Roane Counties. The predominant land uses on the ORR are environmental research, forest management, industry, agriculture, and wildlife management. Approximately 80% of the ORR is forested. The three major DOE industrial and research facilities occupy approximately the following land areas: the K-25 Site, 293 ha (725 acres); the Y-12 Plant, 332 ha (820 acres); and ORNL, 467 ha (1153 acres). The Oak Ridge National Environmental Research Park consists of 8700 ha (21,500 acres) and includes natural* and reference areas* and environmental research sites. Agricultural lands consist mainly of hay fields that are harvested under commercial contracts.

Major public transportation routes within the ORR include State Highways 95, 58, and 327. Highways 58 and 95 carry inter-city traffic to the east, west, and south of Oak Ridge, and Route 327 provides local access to nearby communities north of the ORR.

3.3 ARCHAEOLOGICAL, CULTURAL, AND HISTORICAL RESOURCES

The ORR has a long history of habitation that began an estimated 10,000 years ago with the first occupation by Native Americans. Most recently, four distinct communities (Elza, Scarboro, Robertsville, and Wheat), with a total of ~1000 families, existed within the area acquired by the federal government for the Manhattan Project. Forty-six archaeological sites have been identified on the ORR. Seven DOE-owned structures are listed on the National Register of Historic Places; five of these are on the ORR. Additional potential listings include any buildings or structures related to the Manhattan Project. Thirty-one cemeteries are also present on the ORR.

3.4 GEOLOGY AND SOILS

The ORR lies within the Valley and Ridge Physiographic Province. The Valley and Ridge Province is characterized by steep-sided parallel ridges with broad intervening valleys, generally oriented in a northeast-southwest direction. The ORR lies ~16 km (10 miles) southeast of the Cumberland Mountains and ~113 km (70 miles) northwest of the Blue Ridge Mountains. Elevations on the ORR range from ~230 m (750 ft) above mean sea level (MSL) along the Clinch River to ~385 m (1260 ft) MSL along the highest ridge tops.

The Valley and Ridge Province is part of the southern Appalachian fold and thrust belt. The bedrock stratigraphy of the ORR ranges in age from Lower Cambrian to Upper Ordovician and consists primarily of rock units of the Rome Formation, the Conasauga Group, the Knox Group, and the Chickamauga Group. Some younger rock units are also found.

The Rome Formation is a heterogeneous mixture of sandstone, siltstone, shale, dolomite, and limestone. This formation commonly contains major thrust faults and is internally folded and faulted. On the ORR, the Rome is between 122 m (335 ft) and 450 m (1221 ft) thick. The residual soil of the Rome is a shallow mantle that is generally <5 m (15 ft) thick and consists of sandy, silty, light-colored clay with scattered siltstone and sandstone fragments (Butz 1984).

The Conasauga Group consists of six formations and is estimated to be 560 m (1519 ft) thick (Butz 1984). The ORR is located primarily within the northwestern phase and is composed largely of shale. Areas of the ORR near the boundary of the central phase contain an irregular distribution of layers of limestone within the shale. The Conasauga Group generally weathers to a thin acid soil full of shale chips. Where limestone is present, the resulting soil is deeper and has a higher clay content.

The Knox Group is composed primarily of massive siliceous dolomite. This group generally underlies broad ridges with fairly gentle slopes to the southeast. Thickness of the Knox Group ranges from 900 m (2469 ft) to 1000 m (2743 ft) (Butz 1984). Knox dolomite is very soluble and karst features and sinkholes are common where it is highly fractured. The Knox Group weathers to form deep residual soils with silt and clay content. Knox soils resist erosion because of the abundant chert on the surface. Groundwater is usually quite deep in Knox soils.

The Chickamauga Group is primarily a limestone carbonate with calcareous shales and siltstone. Thickness of the Chickamauga can reach 670 m (2208 ft) (Butz 1984). Chickamauga soils are highly variable but typically consist of clay containing variable amounts of chert. The surfaces of valleys underlain by this group are irregular, with the more silty and cherty layers underlying low ridges and hills. Sinkholes do occur, but are not as numerous nor as large as those found within the Knox Group.

Prime farmlands are protected by the Farmland Protection Policy Act, which seeks "...to minimize the extent to which Federal programs contribute to the unnecessary and irreversible conversion of farmlands to nonagricultural uses ...." [7 *USC* 4201(b)]. Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, oilseed, and other agricultural crops with minimum inputs of fuel, fertilizer, pesticides, and labor, and without intolerable soil erosion. The central issue in assessing impacts to prime farmlands is whether *designated* prime and unique farmlands would be converted to other uses. The undeveloped land on the ORR is owned by DOE and, thus, its use for general agriculture is currently restricted. In addition, because these soils are present on land that is within the city of Oak Ridge, the prime farmland designation is waived, and other uses are permitted (Neal 1995). However, should DOE ownership or land use change in the future, some land being used for sludge application sites could become agricultural land.

3.5 WATER QUALITY

Surface water is drained from the ORR by a network of small streams that are tributaries of the Clinch River. Generally, the tributaries of the Clinch River conform to the physiography of the Valley and Ridge Province by paralleling the Clinch for a long distance before crossing a ridge gap to unite with it. The net effect is a trellis pattern that can be seen on a map such as the topographic map of the Oak Ridge area. Each of the three DOE facilities, the K-25 Site, Y-12 Plant, and ORNL, affects a different subbasin of the Clinch River. Drainage from the Y-12 Plant enters both Bear Creek and East Fork Poplar Creek (EFPC); ORNL drains into White Oak Creek and several tributaries of the Clinch River; and the K-25 Site drains predominantly into Poplar Creek and Mitchell Branch (Energy Systems 1993).

Surface water quality on the ORR is influenced by the geochemistry and soil-water interactions of the subbasins. Water quality is also affected by wastewater discharges and by groundwater transport of contaminants from land disposal of waste. All effluent discharged from ORR facilities to receiving streams must meet various chemical limits that are specified in the NPDES permits for each site (Energy Systems 1993).

Groundwater occurs on the ORR as localized perched water; as transient*, shallow, subsurface stormflow in the unsaturated zone; and as unconfined water tables in the saturated zone. Groundwater quality on the ORR generally is good, with nearly all discharges currently meeting drinking water standards. Nevertheless, groundwater is not used as a source of potable water* on the ORR. Because groundwater may provide a pathway for transport of contaminants from past disposal activities on the ORR, monitoring is being performed in >1400 groundwater monitoring wells to evaluate any current impacts to this resource. Typically, groundwater contamination is most likely to occur from activities in areas of shallow groundwater or in karst areas (Energy Systems 1993).

Water quality in Bear Creek is affected by surface and subsurface drainage from waste burial grounds, an oil landfarm, disposal ponds, and construction-related land disturbances on the Y-12 Plant facility. These sources contribute organic and inorganic chemical contaminants, as well as suspended sediments. In recent years, actions have been taken to reduce the input of contaminants to Bear Creek from several of these sources, and have shown positive results (Southworth et al. 1992).

Concentrations of dissolved salts (primarily calcium, magnesium, sodium, potassium nitrate, chloride, bicarbonate, and sulfate) resulting from the infiltration of contaminated groundwater are higher than in typical unimpacted streams in the region. Trace ions (ammonia, barium, beryllium, cadmium, cobalt, copper, manganese, lead, nickel, silver, uranium, and zinc) are elevated in the uppermost reaches of Bear Creek. Lithium and boron are elevated downstream of the burial grounds. Several metals (cadmium, copper, lithium, nickel, uranium, and zinc) are elevated in the sediments in the upper reaches. Chlorinated solvents and their degradation products enter Bear Creek through north tributaries draining the burial grounds. These organic contaminants are quickly dissipated by volatilization. Polychlorinated biphenyls (PCBs) also enter the creek via these tributaries and are evident in sediments and biota downstream (Southworth et al. 1992).

The water quality of EFPC is also heavily influenced by activities at the Y-12 Plant. Discharges from the Y-12 Plant at the headwaters and from the Oak Ridge POTW near the middle of the stream's length constitute a large percentage of the stream's mean annual flow. The stream also receives urban and agricultural runoff. Water and sediment in EFPC contain metals, organic chemicals, and radionuclides from past operations at the Y-12 Plant. These include ammonia, copper, mercury, nitrogen, petroleum-based oils and greases, perchloroethylene, PCBs, and residual chlorine. Recent actions taken at the Y-12 Plant to reduce the input of contaminants to EFPC have shown positive results in water quality improvement (Southworth et al. 1992).

3.6 FLOODPLAINS AND WETLANDS

No wetlands were identified on any of the sludge application areas when hydrogeologic evaluations of the sites were performed (DOE 1994b). Wetland surveys of all active and inactive sites are scheduled for 1996. Because 40 *CFR* 503 standards and Tennessee guidelines for sewage sludge disposal prohibit application in areas or under conditions that would allow sludge to enter a wetland or other waters of the United States, no sludge is being or would be applied in 100-year floodplains or in wetlands. Figure 3.1 includes wetlands on the ORR.

3.7 CLIMATE AND AIR QUALITY

The Oak Ridge area has a temperate, continental climate. Summers are warm and humid; winters are typically cool. Spring and fall are transitional seasons, normally warm and sunny. Severe weather (e.g., tornadoes or high winds, severe thunderstorms with damaging lightning, extreme temperatures, or heavy precipitation) is rare. Average annual precipitation is ~140 cm (55 in.). The Oak Ridge area has one of the lowest average wind speeds in the United States. Local terrain is the dominant influence on daily wind patterns and contributes to the low average wind speed. Prevailing wind directions are either southwesterly daytime winds or northeasterly nighttime winds. The Oak Ridge area is an attainment area (i.e., within permissible limits) with respect to National Ambient Air Quality Standards for all criteria pollutants (sulfur dioxide, particulate matter, nitrogen dioxide, carbon monoxide, ozone, and lead) (Energy Systems 1993).

3.8 ECOLOGICAL RESOURCES

Terrestrial habitats on the ORR include hardwood forest, pine forest, mixed hardwood/pine forest, pine plantations, open grass/agricultural fields, and industrial areas. Approximately 80% of the ORR is in natural or planted forest. Because of their unique protected status by association with the ORR facilities, several areas of these habitats and associated wildlife have received limited human disturbance since 1942. The ORR was designated as a unit of the

Southern Appalachian Biosphere Reserve within the United Nations' Man and the Biosphere Program. The ORR has also been established as a Wildlife Management Area under a cooperative agreement between DOE and the Tennessee Wildlife Resources Agency (TWRA) and includes the 8700-ha (21,500-acre) Oak Ridge National Environmental Research Park and several state Natural Areas.

Wildlife on the ORR benefit not only from the quality of the habitats available but also from the interspersion (diversity) of the habitats. A diversity of habitats often makes it easier for an individual animal to provide for its needs in a given area of land. However, some species require large unbroken tracts of a single habitat. Many of the wildlife species, such as the white-tailed deer (*Odocoileus virginianus*), are ubiquitous and can be found in almost any habitat, although they may show a preference for a certain type. Other species, such as the yellow-breasted chat (*Icteria virens*), are to be found only in a specific type of habitat. Game animals range from the gray squirrel (*Sciurus carolinensis*) to turkey (*Meleagris gallopavo*) and white-tailed deer. Public deer hunts on the ORR are managed by the TWRA. This is the only hunting activity allowed on the ORR.

Aquatic habitats on the ORR include small streams, Bear Creek, EFPC, the Clinch River, and several scattered ponds. Several species of fish, reptiles, and amphibians are found in these areas. Muskrat (*Ondatra zibethica*) and beaver (*Castor canadensis*) are found close to aquatic areas. The muskrat prefers open terrain where aquatic vegetation and dense growths of riparian grasses, sedges, and rushes exist, and beavers are found in locations where there are trees for food and for building dams and lodges. Mink (*Mustela vison*) and raccoon (*Procyon lotor*) are found in aquatic habitats but range into forest and field areas. Large mammals visit aquatic areas to drink.

Bear Creek generally supports a limited number of fish species with high densities and biomass (Southworth et al. 1992). The uppermost reaches do not have a stable resident fish population, although continued monitoring has shown recovery of fish species and populations in downstream reaches. A weir at Bear Creek kilometer 4.55 acts as a barrier to upstream migration, limiting the number of species found upstream of this site. Monitoring of benthic organisms shows a pattern of increasing density, biomass, and species richness (numbers) and diversity with downstream distance (Southworth et al. 1992).

Ecological studies and monitoring of EFPC have shown population trends and distributions similar to those found in Bear Creek. Fish populations and benthic communities are lower and not as diverse as they should be in a stream of this size. Species richness, diversity, density, biomass, and production are lowest immediately below the Y-12 Plant, and generally increase with distance downstream. Monitoring is showing that recovery is occurring in the lower reaches of EFPC and should continue (Hinzman 1993). Detailed information on the aquatic habitats of these two creeks can be found in Southworth et al. (1992) and the *East Fork Poplar Creek-Sewer Line Beltway Remedial Investigation Report* (DOE 1994a).

3.8.1 Threatened and Endangered Species

Table 3.1 lists state and federal threatened and endangered plant and animal species found on the ORR (Parr 1984; Kroodsma 1987). The gray bat (*Myotis grisescens*), which prefers roosting habitat near water, is one federally listed mammal known to reside on the ORR. Another mammal is the state-listed southeastern shrew (*Sorex longirostris*), which prefers floodplains and wetlands. Federally listed birds found on the ORR include the bald eagle (*Haliaeetus leucocephalus*) and peregrine falcon (*Falco peregrinus*). State-listed birds include Cooper's (*Accipiter cooperi*) hawk, sharp-shinned (*Accipiter striatus*) hawk, and the grasshopper sparrow (*Ammodramus savannarum*), which may nest on the ORR. Several singing individuals were observed during the 1995 breeding season in grassy fields at Freels Bend. Nesting and mating behaviors were also observed. No nests were located, nor were any females or young-of-the-year positively identified.

Figure 3.1 shows the locations on the ORR where state- and federally listed species are known to occur, and their proximity to sludge application sites. It also shows established natural areas for the protection of these species. The following state-listed species have been found adjacent to sludge application sites on the ORR: Tennessee dace (*Phoxinus tennesseensis*), Cooper's hawk (*Accipiter cooperi*), sharp-shinned (*Accipiter striatus*) hawk, tall larkspur

(*Delphinium exaltatum*), Canada lily (*Lilium canadense*), tuberculed rein-orchid (*Platanthera flava* var *hebiola*), purple fringeless orchid (*Platanthera peramoena*), and lesser lady's tresses (*Spiranthes ovalis*). A state-listed fish, the Tennessee dace (*Phoxinus tennesseensis*), is known to occur in Bear Creek and in other streams on the ORR. These locations are shown on Fig. 3.1 as Rare Species Management Areas associated with streams. However, not all aquatic Rare Species Management Areas support the Tennessee dace.

Informal consultation with the TDEC Heritage Program, the TWRA, and the U.S. Fish and Wildlife Service (USFWS) concerning listed species on the ORR is frequently conducted because of many planned or ongoing projects that have the potential for adversely impacting the ecosystem. Field surveys and consultation with state and federal agencies regarding protected species are coordinated and overseen by the ORNL Area Manager for DOE. Active sludge application sites are periodically surveyed for listed species. Inactive sites that may reused are surveyed for protected species and sensitive resources prior to active use. These surveys include site-specific surveys for proposed projects and habitat-specific surveys for species with high likelihoods of occurrence. Occurrence of any listed species is reported to the Heritage Program and to the USFWS by ORNL.

Table 3.1. Status of rare species reported from the Oak Ridge Reservation

		Legal Status [b]	
Species Name	**Common Name**	**Federal**	**State**
	Plants		
Aureolaria patula	Spreading false foxglove	C2	E
Carex gravida	Heavy Sedge		S
Carex oxylepis var. *pubescens*	Hairy Sharp-scaled Sedge		S
Cimicifuga rubifolia	Appalachian Bugbane	C2	T
Cypripedium acaule	Pink Lady's-slipper		E
Delphinium exaltatum	Tall Larkspur	C2	E
Diervilla lonicera	Northern Bush-honeysuckle		T
Draba ramosissima	Branching Whitlow-grass		S
Fothergilla major	Mountain Witch-alder		T
Hydrastis canadensis	Goldenseal		T
Juglans cinerea	Butternut	C2	T
Juncus brachycephalus	Small-headed Sedge		S
Lilium canadense	Canada Lily		T
Liparis loeselii	Fen Orchis		E
Panax quinquefolius	American Ginseng		T
Platanthera flava var. *herbiola*	Tubercled Rein-orchid		T
Platanthera peramoena	Purple Fringless Orchid		T

Rhynchospora colorata	White-topped Sedge		S
Ruellia purshiana	Pursh's Wild-petunia		S
Saxifraga careyana	Carey's Saxifrage		S
Scirpus fluviatilis	River Bulrush		S
Spiranthes lucida	Shining Ladies'-tresses		T
Spiranthes ovalis	Lesser Ladies'-tresses		S
	Fish		
Phoxinus tennesseensis	Tennessee Dace		D
Polydon spathula	Paddlefish	C2	
	Amphibians and Reptiles		
Aneides aeneus	Green Salamander	C2	
Cryptobranchus alleganiensis	Hellbender	C2	D
	Birds		
Accipiter cooperii[d]	Cooper's Hawk		D
Accipiter striatus[d]	Sharp-shinned Hawk		D
Aimophila aestivalis[d]	Bachman's Sparrow	C2	E
*Ammodramus henslowii*C	Henslow's Sparrow	C2	
Ammodramus savannarum[d]	Grasshopper Sparrow		D
Anhinga anhinga[c]	Anhinga		D
Casmerodius albus[c]	Great Egret		D
Chlidonias nigra[c]	Black Tern	C2	
Circus cyaneus[c]	Northern Harrier		D
Contopus borealis[c]	Olive-sided Flycatcher		D
Dendroica cerulea[d]	Cerulean Warbler		C2
Egretta caerulea[d]	Little Blue Heron		D
Falco peregrinus[c]	Peregrine Falcon	T	E
Grus canadensis[c]	Sandhill Crane		D
Haliaeetus leucocephalus[c]	Bald Eagle	T	T
Pandion haliaetus[c]	Osprey		T
[c]	Double-crested Cormorant		D

Phalacrocorax auritus			
Sphyrapicus varius[c]	Yellow-bellied Sapsucker		D
Thryomanes bewickii	Bewick's Wren	C2	T
Tyto alba	Common Barn Owl		D
	Mammals		
Myotis grisescens	Gray Bat	E	E
Sorex longirostris	Southeastern Shrew		D

[a]From Parr and Evans (1992), Cunningham et al. (1993), Kroodsma (1987), Pounds, Parr, and Ryon (1993), King et al. (1994), and ongoing environmental restoration field surveys.

[b]E = endangered, T = threatened, C1, C2 = candidate, D = deemed in need of management, S = special concern in Tennessee.

[c]Uncommon visitor or migrant. Not currently known to nest on the Oak Ridge Reservation.

[d]Summer.

4. POTENTIAL ENVIRONMENTAL IMPACTS

4.1 PROPOSED ACTION

4.1.1 Regional Demography/Socioeconomics

The proposed action would not result in a major net change in employment because no additional personnel would be required to operate the expanded land application program. There would be investment in the construction of two local sludge transfer stations (including a pumping unit and a platform for access to trucks transporting the sludge), but the total value of incremental expenditures associated with the proposed action is estimated to be between $15,000 and $30,000 for ORNL and >$30,000 for the K-25 Site. This investment would be so small relative to the total level of economic activity in the region of influence that the direct impact would be insignificant and no indirect employment would be generated by the expenditure. The action would result in the cancellation of a vendor's contract for sludge drying [past expenditures have been at a rate of $0.66/L ($2.50/gal)], providing a cost savings. Because the vendor has other contracts with other customers and the services provided have been handled by employees not exclusively dedicated to the contract, it would not be expected that this cancellation would reduce area employment.

Assuming that the sewage sludge from ORNL and the K-25 Site and from the city would be disposed of somewhere within the region, a net positive socioeconomic impact (when compared with other reasonable alternatives) results from the use of a sludge application area with restricted public access, a capability for consistent monitoring and data analysis, and no nearby residential areas. Although vector attraction reduction (required by EPA and explained in Appendix G) for the sludge is addressed by the anaerobic treatment process, there has historically been some resistance on the part of a few nearby residents to sludge land application operations. Local residents did not express concern at a local public meeting specifically addressing the proposed action. Keeping all land application sites on the ORR and observing buffer zones* determined by TDEC would avoid proximity to any residential areas.

Environmental Justice

Executive Order 12898 requires federal agencies to achieve environmental justice "to the greatest extent practicable" by identifying and addressing "disproportionately high and adverse human health or environmental effects of its ... activities on minority populations and low-income populations..." For the proposed action and the other alternatives evaluated in this EA, the effects identified would not disproportionately affect any minority group or low-income group. All sludge application sites are on federal land (the ORR), and selection was based on physical criteria such as topography, soil type, and surface features (e.g., avoiding wetlands and floodplains). Site selection was not based on factors (e.g., land value) influenced by socioeconomic criteria such as demographics, income levels, or ethnic composition.

4.1.2 Land Use

Implementation of the proposed action would create no major, long-term negative impacts to land uses and would enhance the hardwood forest management use of several of the application sites (Premier 1995). Long-term land use restrictions would be avoided by following lifetime sludge loading limits, contaminant loading limits, and management controls detailed in the Program Plan (DOE 1994b).

4.1.3 Archaeological, Cultural, and Historical Resources

In compliance with Sect. 106 of the National Historic Preservation Act, DOE consulted with the State Historic Preservation Officer (SHPO) regarding impacts of the proposed action. The response from the SHPO concurs with the DOE determination that the proposed project would have no effect on properties included or eligible for inclusion on the National Register of Historic Places. The letter from the SHPO is included in Chap. 8, Individuals and Agencies Consulted. It should be noted, however, that no sludge is or would be applied on archaeological, cultural, or historical sites.

4.1.4 Geology and Soils

Raising sludge loading limits to TDEC permitted levels, increasing radionuclide levels to RESRAD limits, and including the ORNL and K-25 Site sludges in the sludge application program would not result in any impacts to the area's geology because of the program's operating limitations regarding geologic features such as sinkholes. The soils, however, would experience incremental loading of heavy metals and radionuclides in addition to the nutrients received from the sludge. Protective application limits established by the state, as well as the city's rigorous monitoring program, would ensure that contaminant levels would not exceed benchmarks protective of human health. The future use of the land for agriculture would not only be allowable but would be enhanced by the sludge application. Also, the characteristics of some of the soils, especially those classified as prime farmlands, make these soils among the most suitable for land application of sludge (Neal 1995).

4.1.5 Water Quality

Pathogenic, chemical, or radiological contaminants in sludge applied to land may be transported by surface runoff to receiving waters such as streams, ponds, or wetlands. Potential adverse effects from exposure to these contaminants could occur in aquatic organisms in the surface water or in humans or animals drinking the water or consuming food organisms living in the water. Nitrogen or other nutrients in the sludge could also have potential adverse effects on surface water quality should these nutrients reach excessive levels in the surface water. As explained in *Pathogen Risk Assessment for Land Application of Municipal Sludge* (EPA 1989), the primary source of health risk from land-applied sludge is surface runoff into receiving surface water.

It is for these reasons that EPA's, TDEC's, DOE's, and the city of Oak Ridge's restrictions on land application are stringent with respect to management practices for land application of sludge. For example, Appendix E lists restrictions on land application practices, including the following:

- ideal slopes are <8%, but slopes for surface application may exceed 8% with TDEC approval;
- potential sites must not be located in wetlands or 100-year floodplains;
- potential sites must not be located near U.S. or state waterways (buffer zone distances vary according to sludge class).

These management practices are designed to prevent or minimize any risks of contaminating surface water as a result of land application of sludge. Most of the application sites on the ORR have a heavy herbaceous* cover; reduction of runoff has been related directly to the density of vegetative cover on the site (Sopper 1993).

Sopper (1993) reviewed land reclamation projects using application of municipal sludge. He concluded that "research results on the effects of sludge applications on the concentrations of NO3-N [nitrate-nitrogen], trace metals, and on indicator organisms (fecal coliforms) in soil percolate, groundwater, nearby streams and lakes, and surface runoff indicate that a properly managed land application program will not cause deterioration of water quality on the site." Dutch and Wolstenholme (1994) confirmed these results using a single application of sludge before planting Sitka spruce (*Picea sitchensis*). They found the quality of water draining from the site immediately following sludge application to be satisfactory and levels of nutrients in surface water were still within drinking water quality standards in subsequent months. Although survivability of pathogens in surface water varies, survival is decreased by resident competitive or predatory microorganisms and by solar radiation (EPA 1991a,b).

Surface water monitoring around current sludge application sites has shown no significant degradation of water quality. Surface water sampling from Braden Branch above and below the closed McCoy site showed some nitrate enrichment in the stream from the application site (Boston 1988). Analyses for trace metals showed no significant elevations, and the highest concentrations of regulated metals were still an order of magnitude or more below drinking water standards (Boston 1988). This sampling was performed following heavy rain showers in January 1988; the McCoy site was closed in September 1986 (Boston 1988).

Stream sampling of Bear Creek, performed during an intense storm event on May 1, 1990, below an active application site (Chestnut Ridge) showed minimal increases in the concentrations of measured parameters (organics, heavy metals, and fecal coliform bacteria). The data suggested that runoff from the application site had minimal ecological or human health significance. Subsequent sampling indicated that effects to the water quality of Bear Creek from the runoff during the storm event were largely restricted to a short-term increase in nutrient loading, biological oxygen demand, and fecal coliform bacteria (Boston 1990).

Although some sludge land application areas are located near surface water bodies, no adverse impacts would be expected if the proposed action is implemented. Prior to TDEC approval, a detailed hydrogeological evaluation of each site was completed. This study established the technical suitability of the sites and any need for surface water and/or groundwater monitoring. In addition, EPA land application requirements state that bulk sewage sludge shall not be applied to a site that is 10 m (33 ft) or less from surface waters. As a practice, the city of Oak Ridge has maintained a buffer of 150 m (500 ft) around waters of the state* on sites where sludge has been or is currently being applied. Sludge management practices (Appendix E) also restrict sludge application during precipitation events or when the ground is frozen, thereby minimizing the likelihood of runoff. These practices would continue.

4.1.6 Floodplains and Wetlands

Sludge regulations (40 *CFR* 503), Tennessee guidelines, and site selection criteria (Appendix E) prohibit land application of sludge in areas designated as wetlands and in areas designated as 100-year floodplains. During the hydrogeologic evaluation of the land application sites (Appendix M of DOE 1994b), floodplain areas were identified. No wetlands were found during the hydrogeologic evaluation of the sites (DOE 1994b). All sites, both active and currently inactive, will be surveyed for wetlands in 1996. Sludge application in floodplains and wetlands is and would continue to be prohibited so that no impacts would occur.

4.1.7 Climate and Air Quality

No air quality impacts have been identified for the proposed action. Minor odor problems have been reported from a few past sludge application sites located immediately adjacent to public access highways. Because of the remoteness of most of the sludge application sites, no odor problems to the public would be expected.

A review of the literature indicates spray application of liquid sludge produces a lower level of bacteria (EPA 1991a), viruses (EPA 1992), and parasites (EPA 1991b) in aerosols than does spray application of wastewater and suggests that health risks from aerosolized pathogens are not a serious concern (Pahren 1987; Sorber et al. 1984). When aerosols are generated, as in spray application of liquid sludge, concentrations of microorganisms in liquid sludge suffer an initial rapid die-off known as aerosol shock. This die-off results from sudden pressure changes and the combined effects of relative humidity, temperature, and sunlight. In addition, diffusion in the atmosphere and deposition reduce microbial concentrations with time and distance. Kowal (1985) suggests, however, that the potential for exposure during spray application makes it prudent to limit public access during the application process.

Airborne pathogens resulting from dispersion during land application are very short-lived and, being adsorbed onto liquid or dewatered sludge, are not carried any appreciable distance. Therefore, air quality degradation by pathogens is not expected to be a problem.

4.1.8 Ecological Resources

The proposed addition of the ORNL and K-25 Site sludges to the sludge application program would not be expected to result in any adverse impacts to biota. Effects to most wildlife, especially in the short term, would be limited to physical disturbance from the application vehicle. This low ground-pressure vehicle currently follows the same general route within each application site during sludge application. This localizes direct physical disturbance to a certain degree, creating wide grassed paths (most application sites are grass fields) as opposed to bare-dirt roads through the application sites. Because the application spray generally covers ~30-40 ft laterally (Premier 1995), the spacing between these vehicular paths is ~60-80 ft. Because of the more open nature of the vehicular paths and the slow speed of the vehicle during application, direct mortality of wildlife during sludge application is and would continue to be unlikely.

Surface coating of vegetation and some wildlife does and would occur during sludge application. Most of this coating falls from affected vegetation soon after drying, with most residual sludge being washed off by rain. Vertebrate animals (birds and mammals) are likely to groom and clean themselves of any sludge; it is not known if the incidental ingestion of sludge would have any detrimental effects on wildlife. Studies of sludge applications on mine lands generally have not found adverse effects on the health of domestic or wild animals (Sopper 1993).

Reforestation of some of the application sites to hardwood forests may occur under a separate action (Premier 1995). This reforestation could benefit certain wildlife species. Studies have shown sludge application to have a beneficial effect on hardwood tree plantings (Sopper 1993). Hardwood species also tend to have a better survival rate than conifers on land that has received sludge applications (Sopper 1993). Selection of the tree species used for hardwood reforestation could be based on sludge application practices to benefit replanting efforts, as well as selecting tree species beneficial to desired wildlife species such as deer, turkey, or a species in need of management.

Several studies have been performed on the accumulation of heavy metals by plants and animals from the land application of sewage sludge. These studies show that plants do uptake heavy metals (e.g., cadmium, lead, zinc, copper, nickel) from land-applied sludge, but they suffer no ill effects from the slightly elevated levels they exhibit (Sopper 1993). Likewise, animals that feed on the vegetation or seed of plants with higher than normal levels of heavy metals show no adverse effects. However, like the plants and seeds, the animals show elevated levels of heavy metals in different tissues (Sopper 1993). Cadmium appears to be the heavy metal most commonly accumulated by various animal species. This heavy metal most often accumulates in the liver and kidney tissues. However, uptake of cadmium is selectively reduced in the presence of zinc when the zinc concentration exceeds the cadmium concentration by a factor of 10. Most of these studies (Sopper 1993) involved sites that received annual loading rates that ranged from 25 to 134 metric tons/ha/year (12 to 60 tons/acre/year). These rates are much heavier annual rates of sludge application than those performed on the ORR [9.9 metric tons/ha/year (4.4 tons/acre/year)] and approach or exceed the total loading limit of 110 metric tons/ha (50 tons/acre). It should be noted that most of these studies involved the use of municipal sludge application in the reclamation of lands surface-mined for coal, where acidic soil conditions often enhance the mobilization of existing and any added heavy metals. Sludge applications on mine lands generally have not had an adverse effect on the health of domestic or wild animals (Sopper 1993). Therefore, toxic effects to ecological receptors would not be expected from land application of sludge on the ORR.

4.1.8.1 Threatened and endangered species

Impacts to any state or federally listed species from the proposed expansion of the sludge application program would be avoided or limited by adherence to sludge application regulations (40 CFR 503) and guidelines (Appendix E). The protected natural areas established by the Oak Ridge National Environmental Research Park exclude the application of sludge.

Three federally-listed species are known from the ORR: gray bat (*Myotis grisescens*), bald eagle (*Haliaeetus leucocephalus*), and peregrine falcon (*Falco peregrinus*). The following state-listed species have been found adjacent to the active and potential sludge application areas on the ORR and could be present within these areas: Tennessee dace (*Phoxinus tennesseensis*), Cooper's hawk (*Accipiter cooperi*), sharp-shinned (*Accipiter striatus*) hawk, tall larkspur (*Delphinium exaltatum*), Canada lily (*Lilium canadense*), tuberculed rein-orchid (*Platanthera flava* var *hebiola*), purple fringeless orchid (*Platanthera peramoena*), and lesser lady's tresses (*Spiranthes ovalis*).

The Tennessee dace is a fish listed by the state as "in need of management." The Tennessee dace occurs in headwater streams and is known from several streams on the ORR. Adverse impacts to this and other aquatic species are and would be avoided by strict observance of the program's operating regulations and guidelines, especially with respect to application distances from surface waters. Additionally, the land application of sludge has been shown not to degrade surface water quality (Dutch and Wolstenholme 1994, Boston 1988, Sopper 1993). This was discussed in Sect. 4.1.5, Water Quality.

Pounds, Parr, and Ryon (1993) identify and describe natural areas and reference areas on the Oak Ridge National Environmental Research Park. The Resource Management Organization has approved changes (additions and corrections) to the Oak Ridge National Environmental Research Park natural area system since Pounds, Parr, and Ryon (1993). Updated maps of the Oak Ridge National Environmental Research Park are provided by the ORNL Area Manager and Oak Ridge Environmental Information System. The boundaries of sludge application sites have been adjusted to avoid any natural or reference area. No sludge application is or would be permitted within any designated natural or reference area, nor would sludge application be permitted in any area where a designated aquatic natural or reference area could be affected (Parr 1994).

4.1.9 Potential Radiological Impacts

As described in Sect. 2.1.2, although there are no federal standards for radiological content of sludge and land application areas, under an agreement with DOE, the city of Oak Ridge, and TDEC, the radionuclide levels in the sludge and land application areas are monitored, and risk-based standards for the sludge have been developed (Attachment A of Appendix D). Additionally, workers currently exposed to the sludge (POTW workers or operators of the sludge spreader) are monitored for radiation exposure.

Workers could be exposed to radionuclides in sludge by incidental ingestion and inhalation of sludge particulates during handling of sludge both during treatment and during land application procedures. The health risk analysis in Appendix D concludes that the combined chemical and radiological risks to employees exposed to sludge during the land application process are minimal and are within the EPA target range for excess lifetime cancer risk. Monitoring of employees has shown no detectable exposure to radionuclides (Mobley 1993). Transients could be exposed to the sludge-amended soils. The combined chemical and radiological risks to transients exposed to soil are also minimal and within the EPA target range for excess lifetime cancer risk. Noncarcinogenic risks were estimated to be <1, for both the worker and the trespasser, indicating that no adverse effects would be expected from exposure to sludge or sludge amended soils.

In addition, in >10 years of the program's operation, no adverse health effects have been noted. The truck/field vehicle driver wears a dosimeter, and no significant exposure has been measured. Recent health physics surveys of former sludge land application sites found no significant levels of radionuclide activity on trees, ground cover, or site soil, nor was there evidence of trackout (i.e., no alpha or beta-gamma contamination was detected on personnel or vehicles) (Mlekodaj 1994).

No adverse impacts to human health from radiological constituents would occur from raising radionuclide levels to dose-based limits because risks would be managed so as to remain within the EPA target range.

The addition of sludges from ORNL and the K-25 Site is predicted to constitute an increase of <5% of the current influent. The radiological character of the sludge might change with the addition of sludge from these two facilities because different isotopes are used at these sites than are used at the Y-12 Plant and the other industrial contributors to the Oak Ridge POTW. However, the low levels of isotopic activity in these sludges and the small percentage change in the total POTW influent would make any change in character a factor having little, if any, significant impact on the overall character of the city's POTW sludge. The radiological content (total activity) of the city's POTW sludge would not be expected to change with these additional sludges because these influents would be required to meet the same radiological standards as sludges from other industrial users of the POTW. Because the same land application methodology would be followed, there would be no significant change in total radioactivity delivered to any land application site as a result of the proposed action.

4.1.10 Transportation

Total accidents and casualties (injuries and fatalities) were estimated for transportation of sewage sludge from ORNL and the K-25 Site to the Oak Ridge POTW and from the Oak Ridge POTW to the application sites. "Total vehicle miles of travel" is used as a measure of accident exposure for each destination.

For the purpose of this analysis, it is assumed that two to three truckloads of sewage sludge would be transported from ORNL to the Oak Ridge POTW per month and that one truckload of sewage sludge would be transported from the K-25 Site to the Oak Ridge POTW per month. It is assumed that 3 to 4 truckloads of sewage sludge would be added to the current 40 to 120 loads/month transported from the Oak Ridge POTW to the sludge application sites on the ORR.

The distance from K-25 to the Oak Ridge POTW is ~11 km (7 miles). The distance from ORNL to the Oak Ridge POTW is ~16 km (10 miles). The distance from the Oak Ridge POTW to the application sites averages ~8 km (5 miles).

Based on a total exposure of 1057 vehicle km (657 vehicle miles) of travel and casualty rates as shown in Table 4.1 (Office of Technology Assessment 1988), it would be expected that a total of 6.37E-04 potential accidents and 3.15E-04 potential casualties could occur during transportation of the sewage sludge per month. Increasing lifetime loading limits to TDEC-permitted levels potentially extends the application of sludge up to 10 years. Total potential accidents or casualties in 10 years of sludge application would be <1.

Table 4.1. Highway accident and casualty rates for transportation of sewage sludge

Route	Miles per trip	Trips per month	Total VMT[a] per month	Accident rate[b] (accidents per mile)	Casualty rate[b] (casualties per mile)	Total accidents per month	Casualty accidents per month
ORNL to Oak Ridge POTW	10	2-3	20-30	0.97E-06	0.48E-06	2.91E-04	1.44E-05
K-25 to Oak Ridge POTW	7	1	7	0.97E-06	0.48E-06	6.97E-06	3.36E-06
Oak Ridge POTW to application sites (proposed action)	5	3-4	15-20	0.97E-06	0.48E-06	1.94E-05	9.60E-06
Oak Ridge POTW to application sites (current program)	5	40-120	200-600	0.97E-06	0.48E-06	5.82E-04	2.88E-04
Total	657					6.37E-04	3.15E-04

[a] Vehicle miles traveled.

[b] Accident and casualty rates are from the Office of Technology Assessment (1988).

The potential for contamination to spread during an accident is negligible, based on the conservative assumption that in the case of a spill it would take two people 8 hours to clean up the spill. The excess lifetime cancer risk to an individual (working 16 hours at the spill site) from incidental ingestion of the sludge would be 1E-10 and the excess lifetime cancer risk to an individual from inhalation of the sludge would be 6E-08.

Risks from exposure to pathogens resulting from a spill are generally limited to potential gastrointestinal illness. Most pathogens of concern in sludge are transmitted by the fecal-oral route, so washing hands and avoiding eating in the spill area are typical precautions that would minimize the risk of illness. Individuals with repressed immune systems or sensitive subpopulations such as the elderly or the very young are more at risk from pathogen exposures than are normally healthy adults and children. A transportation hazards assessment (Y-12 1994) determined that the two pathogens of concern in the event of a spill are *Escherichia coli* and *Ascaris lumbricoides*. The report concludes that persons with suspected exposure should report the event and seek medical care as appropriate.

Since the beginning of this land application operation in 1983, there has not been a transportation-related spill. In the event of a spill, there is a spill response plan (DOE 1994b) that includes the initiation of proper spill response measures and the notification of essential oversight personnel.

4.1.11 Human Health and Safety

Human health issues of concern are chemical contamination from the sludge, particularly buildup of heavy metals in the soil, and the survival of pathogens (viruses, bacteria, parasites, and some fungi) in the sludge and soil. These potential health impacts are discussed in Appendix D and summarized here.

Heavy metal concentrations in the sewage sludge are well below the ceiling concentration limits established by EPA (see Table D.1). Because of the historically conservative chemical loading limits of the land application program, chemical contaminants in the receiving soil have remained well below levels of concern for human health effects. As explained in the human health risk assessment (Appendix D), the hazard index (HI) for toxic (i.e., noncarcinogenic) effects from heavy metals is <1, which is within acceptable limits. For cancer effects, risks to the employee applying the sludge and risks to a transient on the sludge application site are well within EPA's target range. However, in the interest of keeping risk as low as reasonably achievable (ALARA), it is possible to reduce risks to workers and transients even further. Risks to employees could be reduced even more by procedural controls during spraying of sludge (e.g., closing the truck window, wearing a mask), and risks to transients could be reduced by restricting the application area to prevent access by transient observers during spraying.

As explained in Chap. 2 of Appendix D, studies indicate that under EPA-approved sludge application practices, pathogens are not a health risk (Kowal 1982; EPA 1988, 1989, 1991a, 1991b, 1992; Sopper 1993). Although some pathogens tend to concentrate in sludge during wastewater treatment, most are inactivated during anaerobic digestion (Sopper 1993), the process used to significantly reduce pathogens at the city of Oak Ridge's POTW. Application of sludge on plants and on the soil surface exposes remaining pathogens to desiccation and sunlight, further reducing the pathogens' survival rate.

EPA requires a 10-m (33-ft) distance from surface water for sludge application to prevent runoff into streams or lakes. However, in practice, the application of sludge by the city on the ORR has been restricted from waters of the state by buffer zones determined by TDEC. Under typical land application conditions, desiccation and sunlight prevent pathogens from surviving long enough or at concentrations high enough to be capable of causing an infection. Adsorption* of pathogenic organisms, as well as chemicals, onto soil particles is the major means for immobilizing these contaminants, generally in the upper 15 cm (6 in.) of the soil surface. Transport of pathogens to groundwater is extremely unlikely unless channels or fissures exist in the soil matrix. For this reason, sludge application is prohibited in areas with rock outcrops, sinkholes, or other geologic features that could act as channels to groundwater. Buffer zones of 15 m (50 ft) around these features aid in preventing contaminants entering groundwater sources.

Activities associated with the transportation of the sewage sludge would comply with DOE notices and regulations on employee health and safety and the spill response plan (DOE 1994b), developed specifically for the transport of sewage sludge from the Oak Ridge POTW to the land application sites.

There are no major occupational health and safety concerns associated with the operations of the truck transporting the sludge and the field vehicle applying the sludge. In the event of a spill, the driver is instructed to follow procedures outlined in the spill response plan. Because there is only one employee operating the truck and the field vehicle, the occupational and health risks (radiological and nonradiological) would be the same as that for the maximally exposed individual (see Appendix D). The public would not be significantly exposed to the sludge unless there is a tanker spill in a populated area, in the event of which the spill response plan would be implemented. Thus the radiological and nonradiological impacts to workers and the public would be within limits established by DOE and the Nuclear Regulatory Commission.

4.2 NO-ACTION ALTERNATIVE

This alternative, which is the continuation of the current sludge application and disposal/storage programs, would involve the current costs at ORNL for thermal drying and sludge disposal at the IWMF and the costs for air drying and storage of K-25 Site sludge at K-1066H (described in Sect. 1.2). The no-action alternative would not provide for beneficial use of this nutrient-rich resource as encouraged by EPA. In addition, low-level waste storage capacity would continue to be used.

Impacts to archaeological/cultural/historical resources, water quality, floodplains and wetlands, climate and air quality, transportation, or human health and safety would not be expected for this alternative and are not discussed further in this section.

4.2.1 Socioeconomics

The no-action alternative would not generate revenues, employment, or population changes that would induce socioeconomic impacts. Current disposal practices for ORNL and the K-25 Site sludge would continue. Land application of sludge on the ORR by the city of Oak Ridge would cease when site loading limits are reached. At that time, other options for sludge management by the city would be required, resulting in non-federal action(s) beyond the scope of this EA.

4.2.2 Land Use

Implementation of the no-action alternative would not change impacts to land use on the ORR. When land application limits are reached at the currently active sites, the sludge generated by the city's treatment plant would have to be disposed of somewhere in the region. Thus, the location of that disposal site could experience land use impacts in some manner elsewhere in the city or county. Continued disposal or storage of the sludges produced at ORNL and the K-25 Site would not result in any land use changes at those two sites (IWMF and K-1066H, respectively) unless formerly unplanned expansions were required to store the additional sludge.

4.2.3 Geology and Soils

No impacts to the geology of the ORR would result from the no-action alternative; impacts are avoided by program-imposed operating limitations (e.g., no application in the immediate area of karst features, such as sinkholes). Until loading limits are reached, soils would continue to receive the monitored application and loading of heavy metals and radionuclides, along with the nutrient-loading and soil improvement benefits. Once loading limits were reached at all approved sites, land application of sludge would cease on the ORR.

4.2.4 Ecological Resources

Continuation of the sludge application program at the current active sites would not be expected to result in adverse impacts to ecological resources of these sites. The application of site evaluation criteria for site approval and the use of sampling and analysis of sludge, soil, and vegetation during site use limits the potential for adverse impacts to occur. Once the loading limits are reached, land application of sludge would cease.

The current sludge application program is not considered to impact any listed species. This is because the currently active sites were selected and approved with the avoidance of any impacts to these species in mind. Most of the active sites are grass and hay fields; few listed species prefer this type of habitat. Exceptions to this include the state-listed grasshopper sparrow, which nests in large grass fields with infrequent mowing, and the state-listed tall larkspur, known from grassy utility corridors on the ORR. Infrequent mowing (or burning), while necessary to maintain an area as grass or weedy grass habitat, could result in negative impacts both to nesting attempts by the grasshopper sparrow and to the flowering and seed production of the tall larkspur. These impacts would occur only if mowing were performed during the reproductive seasons of these species (late April through June for the grasshopper sparrow). In addition, sludge application could harm any grasshopper sparrow nestlings through direct coating with the sludge and through disturbance of the nests by sludge application vehicle. Grasshopper sparrow nests are well-hidden and reasonably protected from rain, which could help limit this type of disturbance. Direct disturbance of any nests by the application vehicle would be limited by the vehicle being operated along the same general route through an application area; these vehicular paths are and would be less desirable nesting areas for the grasshopper sparrow.

If the tall larkspur were found within any of the sludge application sites during the planned protected species surveys, its presence could be attributable to current land management practices (i.e., sludge application and periodic mowing). The effects of sludge application on native plant species composition, species diversity, and species richness is not known. The development of a management plan for the tall larkspur, if present, would be considered.

4.2.5 Radiological Impacts

Under the no-action alternative, the handling and application of sludges using current practices would continue until loading limits are reached, at which time sludge application would cease on the ORR. As explained in the human health risk assessment (Appendix D), there would be no measurable risks to exposed workers or potential transients. Not all sites would necessarily receive the maximum radiological loading limits.

4.3 INDEPENDENT SLUDGE LAND APPLICATION PROGRAMS ALTERNATIVE

4.3.1 Regional Demography/Socioeconomics

This alternative would not result in a major net change in employment because DOE's application program would involve only three to four truckloads per month. The operation and management requirements of an independent DOE application program would not be expected to require any additional full-time employees. There would be investment in the construction of two local sludge transfer stations (including a pumping unit and a platform for access to trucks transporting the sludge), but the total value of incremental expenditures associated with the proposed action is estimated to be between $15,000 and $30,000 for ORNL and >$30,000 for the K-25 Site. The single purchase, lease, or contracting of a field application vehicle would also be a program expense. This total investment would be so small relative to the total level of economic activity in the region of influence that the direct impact would be insignificant. No indirect employment would be generated by these expenditures. This alternative would result in the cancellation of a vendor's contract for sludge drying at ORNL [past expenditures have been at a rate of $0.66/L ($2.50/gal)]. The partial business loss to this vendor would be offset by the personnel requirements to operate and manage DOE's application program; therefore, it would not be expected that this cancellation would significantly reduce area employment.

An independent DOE application program would continue to provide for the beneficial use of sludge by both DOE and the city on application areas with restricted public access, a capability for consistent monitoring and data analysis, and no nearby residential areas. Keeping all land application sites on the ORR and observing buffer zones determined by TDEC would avoid proximity to any residential areas.

4.3.2 Physical and Ecological Resources

The limited potential impacts, both positive and negative, to the physical and ecological resources of the ORR have been discussed in , Propose Sect. 4.1 Action. These resources include land use; archaeological, cultural, and historical resources; geology and soils; water quality; floodplains and wetlands; climate and air quality; and ecological resources. The proposed action would add DOE sludges to the existing city's sludge land application program; the implementation of this alternative would result in the operation of separate DOE and city application programs on the ORR. Separate application programs would involve the same application sites and sludge volumes as the proposed action, resulting in nearly identical impacts as those within the proposed action. A few resources could receive negligibly increased negative impacts from this situation, such as the local air receiving exhaust emissions from two field application vehicles operating simultaneously on the ORR 3 or 4 days a month. Management coordination of application volumes and/or sites between the two programs would be necessary to preclude any impacts resulting from unknowingly exceeding land loading limits.

4.3.3 Potential Radiological Impacts

The total radiological content (total activity) of sludges applied on the ORR would not be expected to change because the combined ORNL and K-25 Site sludges would be required to meet the same radiological standards as sludges from the POTW. Because the same land application methodology would be followed, there would be no significant change in total radioactivity delivered to any land application site as a result of the implementation of a separate DOE sludge land application program.

4.3.4 Transportation

Under this alternative, an additional tanker would be transporting sludge for the DOE application program. Three to four truckloads of sludge per month would be hauled to application sites on the ORR. Several transportation scenarios could develop under this alternative, the most likely to occur being two to three truckloads per month of sewage sludge being hauled from ORNL and then to the application sites, and one truckload being hauled per month from the K-25 Site to the application sites. This would reduce the distance estimated for sludge transport within the proposed action and lower the rates for potential accidents and casualties.

4.3.5 Human Health and Safety

The human health risks, for worker and transient, associated with this alternative would be essentially the same as those for the proposed action, i.e., carcinogenic risks within EPA's target range and noncarcinogenic risks below an HI of 1. However, because different workers would be applying the sludge, each would have a lower risk than if one worker were responsible for all the sludge application.

4.4 DOE APPLICATION PROGRAM AND DISCONTINUATION OF CITY'S APPLICATION PROGRAM ON THE ORR

4.4.1 Regional Demography/Socioeconomics

The implementation of a DOE application program along with the discontinuation of the city's application program on the ORR would incur the same costs to DOE as the independent application programs alternative. However, the loss of the ORR application sites to the city's program could result in substantial cost changes in the city's program. The city might have to lease or purchase alternate application sites or change to a completely different sludge management strategy.

4.4.2 Physical and Ecological Resources

The limited potential impacts, both positive and negative, to the physical and ecological resources of the ORR have been discussed in Sect. 4.1, Proposed Action. These resources include land use; archaeological, cultural, and historical resources; geology and soils; water quality; floodplains and wetlands; climate and air quality; and ecological resources. The proposed action would add DOE sludges to the existing city's sludge land application program; the implementation of this alternative would result in the operation of only a DOE application program on the ORR. Such a program, operating at 5% of the volume of the current program, would reduce any expected impacts, though not necessarily in proportion to the amount of volume reduction. For example, the benefit of a lowered level of bacteria (EPA 1991a) from the spray application of liquid sludge would still be effective. Likewise, the potential impacts to surface water from a transportation spill would remain the same, but the probability of such a spill occurring would be reduced from the fewer truckloads of sludge being transported.

4.4.3 Potential Radiological Impacts

With the cessation of the city's sludge application program, the total radiological content (total activity) of sludges applied on the ORR would be expected to decrease significantly. The combined ORNL and K-25 Site sludges would be required to meet radiological standards and would be applied at greatly reduced volumes when compared to the city's current program, thereby reducing the total radioactivity delivered to land application sites on the ORR.

4.4.4 Transportation

Transportation risks under this alternative would be identical to those that would occur under the independent application programs alternative.

4.4.5 Human Health and Safety

Because the sludge applied on the reservation would be only about 5% of the former total application, the risk to worker and transient would be extremely low, well below EPA's target range for carcinogenic risk and well below the HI of 1.

4.5 COMPARISON OF ALTERNATIVES

Table 4.2 summarizes and compares the alternatives and their impacts.

Table 4.2. Comparison of alternatives

Action	Summary	Impacts
Proposed Action: Raise sludge lifetime loading limits to 50 tons/acre, increase radionuclide	Minor increase (5%) in quantity of sludge applied on the ORR; reduced costs for ORNL	Negligible increase in

loading to 10 mrem/year dose-based RESRAD limits, and add ORNL and K-25 Site as industrial customers of the Oak Ridge POTW and thus to the sludge land application program on the ORR	and K-25 Site sludge management; beneficial use of sludge on the ORR; extends life of sludge application program because of higher loading limits on existing sites	health, environmental, and transportation risks over baseline
No Action: Continued sludge application on the ORR until current loading limits reached; thermal drying and disposal of ORNL sludge and air drying and storage of K-25 Site sludge	Existing sludge application program would reach loading limits and application on ORR would cease; continued high costs for sludge management at ORNL and K-25 Site; use of limited availability waste storage and disposal capacity instead of beneficial use of sludge	No additional impacts beyond current situation
Independent sludge application by DOE on the ORR and continued sludge application by Oak Ridge on the ORR	DOE would duplicate city's LAA, sampling/analysis/reporting, cost for field application vehicle, administrative and logistics cost	Minimal increase in health, environmental, and transportation risks over baseline
Sludge application by DOE on the ORR and discontinuation of sludge application by Oak Ridge on the ORR	Increase long-term availability of application sites because of reduced sludge quantity (~5% of current loading); city would have to find alternative sites or sludge management methods	Substantial reduction in health, environmental, and transportation risks relative to baseline on the ORR

5. POTENTIAL CUMULATIVE AND LONG-TERM IMPACTS

The lifetime loading limits, ceiling concentrations for heavy metals, and the comprehensive monitoring program are designed to prevent future land use restrictions from being placed on any sites used for land application of sludge. The safety factor provided by the specific limits derived from the TDEC-approved risk-based approach ensures protection of the environment.

Table 5.1 through 5.4 summarize cumulative loading of inorganics, heavy metals, organics, radionuclides, respectively, on active ORR sludge application sites. These tables give an indication of how minimal the cumulative impacts would be. For example, concentrations of heavy metals (Table 5.1) are well below the EPA risk-based limits, as described in Sect. 2.1.2. The ongoing monitoring program also makes it possible to document contaminant levels should regulatory limits be modified in the future. Tables 5.2, Tables 5.3, and Tables 5.4 illustrate that cumulative impacts from inorganics, organics, and radionuclides are not important. In fact, radiation levels in several samples of sludge application soils are equivalent to or even below reference levels from sites not receiving sludge applications. Radionuclide levels in soil are tested annually at sludge land application sites. Table 5.4 compares the levels of several radionuclides at five application sites to those at adjacent reference areas where sludge was not applied. In most instances, the radionuclide levels in application areas are similar to those in reference areas. The only area in which the historical goal of 2× background for long-lived radionuclides was exceeded was for strontium-90 and technetium-99 at the Hayfield #2 site, but these were very low levels of activity that are well below risk-based levels. Hayfield #1 exhibited levels of cobalt-60 higher than 2× background. However, DOE has made an exception in the case of cobalt because it has a relatively short half-life of 5.28 years. The generally very low levels have been confirmed by recent monitoring data showing no detection of radiation above background levels at any of the sludge application sites surveyed (Mlekodaj 1994).

Impacts to human health are evaluated in Appendix D. Combined chemical and radiological risks to employees and transients are minimal and are within the EPA target ranges for excess lifetime cancer risk and for nonradiological hazard. Cumulative human health impacts would be expected to be less than those described in Appendix D for direct exposure to sludge during or immediately after land application. Monitoring of employees has shown no significant exposure to radionuclides (Mobley 1993).

No ecotoxicological impacts would be expected from cumulative exposures to ecological receptors.

The ORR covers 13,969 ha (34,516 acres). The three major facilities occupy 1092 ha (2698 acres). The National Environmental Research Park consists of 8700 ha (21,500 acres) and includes designated natural and reference areas and environmental research sites. The active and currently inactive sludge application sites total 92 ha (227 acres). This represents 0.7% of the total area of the ORR. The size of application sites ranges from 4.9 ha (12 acres) to 18.2 ha (45 acres).

Operations at the Y-12 Plant result in chemical and radionuclide releases to EFPC and Bear Creek; these releases are controlled and monitored. Ongoing studies show these releases and their effects on the biological systems of these streams to be greatly reduced from historical levels (Energy Systems 1993). The proposed addition of ORNL and K-25 Site sludges to the sludge application program would not be expected to result in any cumulative impacts to these streams. This is based on the low levels of releases from the Y-12 Plant, thelow levels of contaminant concentrations in the sludge, and the strict regulations governing the application of sludge near surface waters.

Table 5.1. Cumulative heavy metal loading levels on active ORR sludge land application sites versus 40 CFR 503.13(b)(2) limits

	Cumulative pollutant loading levels as of 12/31/95[a]					
Heavy metal	High pasture	Scarboro Road	Hayfield #1	Hayfield #2	Watson Road	40 *CFR* 503.13 cumulative loading limits
Arsenic	0.06	0.17	0.17	0.19	0.14	41
Cadmium	0.11	0.32	0.33	0.38	0.31	39
Copper	6.16	18.48	19.37	21.74	15.68	1500
Lead	0.89	2.8	2.91	3.24	2.35	300
Mercury	0.78	2.24	2.35	2.57	1.90	17
Nickel	0.50	1.38	1.45	1.62	1.24	420
Selenium	0.09	0.25	0.26	0.30	0.19	100
Zinc	21.3	63.7	66.7	74.7	53.87	2800

Source: City of Oak Ridge 1996.

[a] Total amount of pollutants applied over life of site in kg/ha.

Other activities on the ORR that could result in cumulative impacts are salvage logging operations and environmental restoration activities. Salvage logging was begun during 1993 in several of the pine plantations on the ORR because of an infestation of the southern pine beetle. Logging operations result in considerable disturbance of the soil surface, creating a potential for erosion and transport to aquatic systems. Long-term beneficial impacts to hardwood reforestation efforts on some of the sludge application sites could be expected (Chapman-King, Hinckley, and Grier 1990).

Environmental restoration activities may be performed along sections of EFPC, Bear Creek, or their tributaries during the same time period that the sludge application sites would be in use. Excavation or construction-type activities associated with restoration could result in some short-term sediment loading of streams. Sludge application would not be expected to result in adverse cumulative impacts because of the strict regulations governing the application of sludge near surface waters. The operating history of the current sludge application program shows the city of Oak Ridge to be rigorous in complying with these and other regulations.

Table 5.2. Cumulative inorganics loading levels on active ORR sludge land application sites

	Highest detected soil level									
Analyte	High pasture		Scarboro Road		Hayfield #1		Hayfield #2		Watson Road	
Year	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
Cation exchange capacity[a]	7.20	11.0	9.86	7.4	7.80	13.0	11.87	9.4	13.63	12.0
Manganese[b]	2189.0	3140.0	1683.0	1300.0	697.0	5300.0	2373.0	727.0	3290.0	1730.0
pH	4.7	6.0	5.4	5.2	5.2	5.0	4.9	5.8	5.5	5.4
Phosphorus[b]	143.7	160.0	146.0	370.0	148.7	360.0	122.0	1000.0	111.0	18.0
Potassium	91.3[b]	0.36[a]	154.0[b]	0.30[a]	175.7[b]	0.37[a]	98.3[b]	0.69[a]	109.7[b]	0.32[a]
Priority pollutants (those found in the sludge)[c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Kjeldahl Nitrogen[d]	2143	3200	3097	2100	2977	1700	2780	3700	1513	680

Source: City of Oak Ridge 1994, 1995.
[a] Analyses are in meq/100 g.
[b] Analyses are in mg/kg dry weight.
[c] No priority pollutants were detected in the city of Oak Ridge sludge for 1993 or 1994.
[d] Analyses are in mg-N/kg.

Table 5.3. Cumulative organic compound loading levels on active ORR sludge land application sites

Analyte	Application site	Highest detected soil level in 1993[a]
Heptachlor Epoxide	Scarboro Road	4.9
Alpha-Chlordane	Hayfield #1	7.2
Gamma-Chlordane	Hayfield #2	6.9
Bis(2-Ethylhexyl) Phthalate	Hayfield #1	0.2

Source: City of Oak Ridge 1994.
[a] Analyses are in mg/kg dry weight.

Table 5.4. Cumulative radionuclide loading on active ORR sludge land application sites

	Cumulative radionuclide loading on indicated site, pCi/g									
	Hayfield #1		Hayfield #2		High Pasture		Watson Road		Scarboro Road	
Selected radionuclide	Ref[a]	Total[b]	Ref	Total	Ref	Total	Ref	Total	Ref	Total
Potassium-40	3.0	2.7	3.0	4.8	3.1	4.1	11.2	7.4	4.0	3.8
Cobalt-60	0.01	0.05	0.01	0.01	BLD[a]	0.06	BLD[a]	0.01	BLD[a]	0.03
Strontium-90	0.07	0.12	0.07	0.19	0.12	0.14	0.15	0.17	0.18	0.17
Technetium-99	0.01	0.01	0.01	0.05	0.04	0.08	0.06	0.09	BLD[a]	0.04
Cesium-137	0.54	0.57	0.54	0.77	0.47	0.45	0.54	0.59	0.48	0.81
Uranium - total	2.8	3.6	2.8	3.2	2.3	3.4	3.0	2.9	2.4	3.2

[a]Assumed background radiation for given site based on radioanalysis of soil taken from adjacent site not used for sludge; BLD signifies radionuclide measurement below level of detection.

[b]Radionuclides found in top 15 cm of application site soil by lab radioanalysis of samples taken in 1992 and 1993, values include background.

6. PERMIT AND REGULATORY REQUIREMENTS

EPA regulates municipal sewage sludge disposal under the Clean Water Act (40 *CFR* 503), with the Congressional mandate to reduce the potential environmental risks and maximize the beneficial use of sludge (Sopper 1993). In Tennessee, TDEC is currently seeking delegated authority from EPA for local sludge management under 40 *CFR* 503 regulations.

Participation in the land application operation would require ORNL and the K-25 Site to meet the city of Oak Ridge pretreatment program limits and obtain an Industrial and Commercial User Waste Water Discharge Permit like the example permit (Appendix B) issued to the Y-12 Plant. In addition, the city of Oak Ridge possesses an NPDES permit and an LAA for the preparation and application of sludge. These are issued by the state of Tennessee and would be reviewed in the event that K-25 Site and ORNL sludges are added to the city's POTW. It may be necessary to include stormwater outfalls from the sludge application sites in the NPDES permits for one or more of the DOE facilities on the ORR. DOE and Energy Systems would, at that time, probably need to decide which ORR sites would need to carry outfalls on the NPDES permit.

If DOE instituted an independent land application of ORNL and K-25 Site sludges, LAA letters from TDEC would be required and sampling, analysis, and reporting requirements would take effect.

Currently, the Sludge Application Working Group, composed of representatives from the city, DOE, Energy Systems, and TDEC, identifies and resolves issues and concerns related to the ORR sludge application program. The purpose of the group is to provide technical management, reduce operational risks, minimize short- and long-term liability, and identify and evaluate long-term alternatives to the current process. Technical oversight is provided by the Principal Investigator of the Energy Systems Waste Management Organization, an independent program oversight advisor, and the Sludge Application Working Group.

It is the policy of DOE to keep radiation exposures ALARA below applicable dose limits. DOE notices and regulations specifically require the application of the ALARA process for radiation protection of workers and the public and the environment. DOE (1991) provides interim guidance on the procedures for applying the ALARA process for compliance with DOE 5400.5. The guidance states that both "...DOE Orders and regulations recognize that ALARA decisions require consideration of a broad range of technical and social considerations and recommend that the bases for ALARA judgments be documented." ALARA considerations are identified throughout the text of this analysis.

The TDEC Division of Radiological Health regulates discharges of radionuclides to POTWs by licensed nuclear material facilities under *State Regulation for Protection Against Radiation*. In Oak Ridge, sewer effluents are specifically regulated for each licensee by a license condition; the limits for the license conditions are set via consultations between the city of Oak Ridge POTW and the Division of Radiological Health. Generic effluent radiological release limits are lower than those of the Nuclear Regulatory Commission.

Because the excreta from individuals undergoing medical diagnosis or therapy with radioactive material are not subject to certain limitations of the regulations governing discharges to the sanitary sewer system, the hospital in Oak Ridge notifies the POTW operator when radioisotope procedures are being done that will lead to releases to the sewer system. This notification is designed to protect sewer maintenance workers from unnecessary exposures.

DOE regulates its discharge of radionuclides to sewers in DOE Order 5400.5: "...the control of releases of liquid wastes to community sanitary sewer systems is designed to be generally consistent with requirements imposed by the Nuclear Regulatory Commission on its licensees..." (Chapter I, Sect. 7) (Stephenson 1994a). DOE Order 5400.5 specifies concentration discharge limits for radionuclides. Regulation of source, special nuclear, and by-product material was reserved to the Atomic Energy Commission under the Atomic Energy Act of 1954, as amended. That regulatory authority passed to the Atomic Energy Commission successor agencies: the Nuclear Regulatory Commission (and agreement states, including Tennessee, for privately-owned nuclear facilities) and DOE (for its government-owned nuclear facilities).

DOE regulation currently applies to the radionuclides in Y-12 Plant sewage discharges and would also apply to radionuclides in ORNL and K-25 Site sewage sludge being added to the city of Oak Ridge POTW; however, both ORNL and the K-25 Site would be required to meet pretreatment standards and prescribed sanitary discharge limits as required of the Y-12 Plant and other industrial sewage generators in order to be compatible with the city's industrial sewage pretreatment program.

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8. INDIVIDUALS AND AGENCIES CONSULTED

Dr. Lee A. Barclay
Field Supervisor
U.S. Fish and Wildlife Service
446 Neal Street
Cookeville, Tennessee 38501

Terry Gupton
District Conservationist
Natural Resources Conservation Service
Roane County Soil Conservation District
U.S. Department of Agriculture
P.O. Box 206
Kingston, TN 37763

Herbert L. Harper
Executive Director and Deputy State Historic Preservation Officer
Tennessee Historical Commission
701 Broadway, B-30
Department of Environment and Conservation
Nashville, Tennessee 37243-0442
tel: (615) 532-1550

Alan W. Neal
District Conservationist
Natural Resources Conservation Service
Anderson County Soil Conservation District
U.S. Department of Agriculture

319 S. Main Street
Clinton, TN 37716

Jack Robinson, Jr.
Wastewater Treatment Supervisor
City of Oak Ridge
P.O. Box 1
Oak Ridge, Tennessee 37831-0001

9. LIST OF PREPARERS

This EA was prepared by DOE with contractual assistance from Science Applications International Corporation (SAIC). The following SAIC staff members contributed to the preparation of this report.

Name	Degree/Discipline	Professional experience	Responsibility
Ernie Burress	B.S. - Anthropology	12 years experience in environmental impact assessment	Technical review
Elizabeth D. Caldwell	Ph.D. - Ecology M.S. - Radiation Ecology B.S. - Medical Technology/Microbiology	12 years of experience in human health risk assessment, including mixed waste, radiological, and chemical exposure assessments	Human health risk assessment task leader
Maureen Cunningham	Ph.D (expected 1996) - Ecology M.S. - Botany B.A. - Botany	9 years of experience in environmental impact assessment, rare species surveys and distribution	Technical review
Michael Deacon	B.S. - Environmental Studies B.S. - Environmental Health	4 years of experience in environmental impact assessment	Environmental impacts analysis
Linda Higginbotham	Ed.D. - Ed. Admin. & Supv.	10 years of experience in statistical design and data analysis	Word processing and editing
Ruth Maddigan	D.B.A. - Business Economics/Quantitative Business Analysis M.S.B.A. - Management B.S. - Mathematics A.B. - Economics	14 years of experience in economic impact analysis; 4 years of experience in environmental impact assessment preparation	Socioeconomics/Demographics
Lucy Nordgaard	B.A. - Journalism	15 years of experience in technical writing/ editing and public information	Technical writer/editor

Calvin Wenzel	B.S. - Biology	20 years of experience in environmental impact assessment and environmental impact statement preparation	Environmental impacts analysis
Marialice Wilson	M.S.L.S. - Biomedical Information B.S. - Biology	16 years of experience in risk assessment, toxicology, environmental assessment, and environmental impacts analysis; 6 years of experience in sewage sludge pathogen risk assessment	Principal Investigator

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(1) Text followed by an asterisk is defined in the glossary.

FINDING OF NO SIGNIFICANT IMPACT

CHANGES IN THE SANITARY SLUDGE LAND APPLICATION PROGRAM ON THE OAK RIDGE RESERVATION,OAK RIDGE, TENNESSEE

AGENCY: U.S. DEPARTMENT OF ENERGY

ACTION: FINDING OF NO SIGNIFICANT IMPACT

SUMMARY: The U.S. Department of Energy (DOE) has completed an environmental assessment (DOE/EA-1042) that evaluates potential impacts of proposed changes in the sanitary sludge land application program on the DOE Oak Ridge Reservation (ORR), Oak Ridge, Tennessee. Changes in lifetime sludge land application limits and radionuclide loading are proposed, and two new sources of sewage sludge from DOE facilities would be transported to the City of Oak Ridge Publicly Owned Treatment Works (COR POTW). Lifetime sludge land application limits would increase from 22 tons/acre to 50 tons/acre, which is the limit approved and permitted by the Tennessee Department of Environment and Conservation (TDEC). With the approval of TDEC, the permissible radiological dose from sludge land application would change from the current limit of 2× background radionuclide concentrations in receiving soils to a risk-based dose limit of 4 millirem (mrem) per year for the maximally exposed individual. Sludge land application sites would not change from those that are currently part of the program. Based on the results of the analysis reported in the EA, DOE has determined that the proposed action is not a major federal action that would significantly affect the quality of the human environment within the context of the National Environmental Policy Act of 1969 (NEPA). Therefore, preparation of an environmental impact statement (EIS) is not necessary, and DOE is issuing this Finding of No Significant Impact (FONSI).

PUBLIC AVAILABILITY OF EA AND FONSI: The EA and FONSI may be reviewed at and copies obtained from

U.S. Department of Energy

Public Reading Room

55 Jefferson Circle, Rm 112

Oak Ridge, Tennessee 37830

Phone: (423) 241-4780.

FURTHER INFORMATION ON THE NEPA PROCESS: Further information on the NEPA process and DOE NEPA regulations may be obtained from

Patricia W. Phillips

NEPA Compliance Officer

U.S. Department of Energy

P. O. Box 2001

Oak Ridge, Tennessee 37831

Phone: (423) 576-4200.

BACKGROUND: The U.S. Environmental Protection Agency (EPA) supports the beneficial use of municipal sewage sludge for fertilizer and soil conditioner on federal lands (56 *Federal Register* 30448). Since 1983, with the approval of theTennessee Department of Environment and Conservation (TDEC) and the DOE, sewage sludge from the City of Oak Ridge Publicly Owned Treatment Works (COR POTW) has been applied as a beneficial soil amendment to sites on the Oak Ridge Reservation (ORR). Sludge having 2 to 3% solids is applied to ORR sites from a tanker truck at an annual rate of 4.4 dry tons/acre/year. Like many municipal sewage sludges, the COR POTW sludge contains trace amounts of heavy metals and radionuclides. However, by law, it is exempt from regulation as a hazardous substance under the Resource Conservation and Recovery Act (RCRA) and is regulated by TDEC, Division of Water Pollution Control, in accordance with Section 405 of the Clean Water Act. Results of periodic analyses of sludge application site soils and vegetation indicate that concentrations of heavy metals, organics, inorganics, radionuclides, and pathogens are below regulatory limits.

The proposed action consists of three changes in the current sludge land application program: (1) an increase in the lifetime loading limit for land application of sludge on the ORR from DOE's self imposed, conservative limit of 48 metric tons/ha (22 tons/acre) to the TDEC-permitted level of 110 metric tons/ha (50 tons/acre); (2) a change in radionuclide loading limits from 2×background radionuclide concentration in receiving soils to radionuclide concentration limits in sludge based on a dose limit of 4 millirem (mrem) per year using a TDEC-approved, risk-based model; and (3) the transport of sanitary wastewater treatment plant sludge from the DOE Oak Ridge National Laboratory (ORNL) and K-25 Site sewage treatment facilities to the COR POTW for inclusion in the land application program. DOE action is needed to reduce the costs of storing and disposing of ORNL and K-25 sewage sludges onsite and to obtain additional beneficial use of the sludges.

ALTERNATIVES: The no-action alternative was considered in accordance with DOE NEPA regulations (10 CFR 1021) to provide a baseline for comparison with the proposed action and alternatives. If no action is taken, ORNL and K-25 Site sewage sludges would not be transported to the COR POTW, and sludge management at these facilities would continue as currently practiced. The lifetime sludge land application limit and radionuclide loading limits would remain at current levels. As a consequence, as ORR sites reach lifetime loading limits, the COR would need to use alternative methods for disposing of its POTW sludge.

Other reasonable alternatives considered were (1) continuation of COR sludge application on the ORR combined with a DOE program for ORNL and K-25 sludge application on the ORR; and (2) discontinuation of the COR sludge application program and implementation of a DOE program for application of ORNL and K-25 sludge on the ORR. Composting, shallow land burial, incineration, and offsite disposal of ORNL and K-25 sludges were dismissed from detailed consideration because either they do not meet the immediate need for management of DOE sewage sludges, are prohibited by a regulatory agency, or do not result in the beneficial use of sludge application.

ENVIRONMENTAL IMPACTS:

Socioeconomics

Because additional personnel would not be needed to continue the sludge land application program on the ORR or to operate the COR POTW, a net change in employment would not be realized. The less than $100,000 investment needed for construction of new sludge transfer stations would not impact the local economy. The addition of ORNL and K-25 sewage sludges to the COR POTW would add less than 5% to its existing sludge generation which is well below maximum treatment capacity.

Environmental Justice

Potential impacts from the proposed action would be minor and would be restricted to the ORR. Thus, minority or low-income populations in the Oak Ridge area would not be disproportionately affected.

Land Use

Impacts to ORR land use would be positive. Application of sewage sludge enhances the soils at specific sites, improving hay production and hardwood growth, and assisting in restoring disturbed sites to a natural state. Offsite land use would not be affected by the proposed action.

Cultural Resources

In compliance with Section 106 of the National Historic Preservation Act, DOE consulted with the Tennessee State Historic Preservation Officer (SHPO) regarding potential impacts to archaeological, historic, and cultural resources on the ORR. The SHPO determined that no adverse impacts would result from the proposed action. Sludge application is prohibited in known archaeological and historic sites on the ORR.

Geology and Soils

Sludge application sites are prohibited in areas with known geological features, such as sinkholes. Both positive and negative impacts to soils result from the sludge land application program. In addition to the nutrients derived from the sludge, soils also receive heavy metals and radionuclides in trace quantities. Monitoring of specific soil constituents is performed regularly as prescribed by EPA and TDEC to protect public health and the ecosystem. Hence, significant adverse effects would not be expected.

Water Resources

Without the implementation of stringent sludge land management practices specified by EPA, TDEC, DOE, and the COR, pathogenic, chemical, and/or radiological contaminants in sewage sludge could be transported to streams, ponds, and wetlands on the ORR. Such contamination could adversely affect aquatic organisms and ultimately man through bioaccumulation in the food chain. Management practices used to minimize the potential for significant impacts include limitations on land slope, prohibition of sludge application sites in wetlands and floodplain, restrictions on sludge application during precipitation and extreme cold, and establishment of minimum buffer zones between application sites and federal and state waterways. Vegetative cover is also used to reduce site runoff. To date, surface water monitoring on the ORR has shown no evidence of significant water quality degradation. Continuation of the program, as currently implemented, would not be expected to adversely impact ORR and offsite water resources.

Air Quality

Atmospheric emissions from sludge application are limited to aerosols generated by spraying liquid sludge on land areas. Diffusion and deposition of chemical constituents and microbes in the aerosols increases with time and distance from the application sites. Public access to the ORR is restricted, therefore, it is unlikely that humans would be affected by spray applications. Unpleasant odors from sludge have been reported from ORR application sites near public highways, but away from residential areas. These odors would be a temporary nuisance, but they would not cause significant adverse impacts.

Ecological Resources

Significant adverse effects to biota would not result from the proposed action. The physical presence of sludge application vehicles would temporarily disturb and displace resident wildlife. Direct mortality would be minimal. Studies on the bioaccumulation of heavy metals from sludge by plants and animals report no ill effects from slightly elevated concentrations in body tissues. Although state-listed and federally listed threatened and endangered species are known to occur on the ORR, none have been adversely affected by sludge application at specific ORR sites. DOE's ecologists at ORNL routinely and frequently consult with TDEC, the Tennessee Wildlife Resources Agency, and the U.S. Fish and Wildlife Service to ensure that protected species and habitat are not adversely impacted by the sludge land application program and other DOE actions on the ORR.

Occupational and Public Health and Safety

Radiological: Workers may be exposed to radionuclides in sludge by incidental ingestion and inhalation of particulates during handling and application. The health risk analysis conducted for this proposed action concludes that the combined chemical and radiological risks to workers would be minimal and within the EPA target range for excess lifetime cancer risk (10^{-6} to 10^{-4}). Monitoring of sludge application program workers for more than a decade has shown no detectable exposures to radionuclides. Offsite, the public exposure to radionuclides in the sludge applied on the ORR would continue to be low, although the basis for calculating radiological dose would change. The proposed dose limit of 4 mrem/year was established with the approval of TDEC because it is protective of human health and the environment.

Based on estimates of accidents and casualties from transport of sewage sludge from ORNL and K-25 to the COR POTW, impacts would be insignificant. Total potential accidents and casualties over 10 years of sludge application would be less than 1. Cancer risk from occupational exposure to sludge spilled in an accident would be 1×10^{-10}, which is extremely low when compared to the risk of cancer from natural causes (2.5×10^{-3}). Risk to the public from a spill would be negligible.

Nonradiological: With improper management, worker and public health could be adversely affected by accumulation of heavy metals and pathogens in the soil, which in turn are accumulated in food and water. Because the historically conservative loading limits of the program have been less than EPA and TDEC limits established to protect human health, chemical contaminants in receiving soils have remained below acceptable levels. Proposed changes to the program would continue to restrict sludge loading to the limits established by EPA and TDEC.

DETERMINATION: Based on the findings of DOE/EA-1042, DOE has determined that the proposed changes in the sanitary sewage sludge land application program on the Oak Ridge Reservation, Oak Ridge, Tennessee, do not constitute a major Federal action that would significantly affect the quality of the human environment within the context of the National Environmental Policy Act. Therefore, preparation of an environmental impact statement is not required.

James C. Hall Manager
U.S. Department of Energy
Oak Ridge Operations Office
Oak Ridge, Tennessee

APPENDIX A - EXAMPLE LAND APPLICATION APPROVAL LETTER FROM TDEC SHOWING LIMITS AND CONDITIONS IMPOSED ON OPERATIONS OF SLUDGE APPLICATION SITES

APPENDIX B - EXAMPLE WASTEWATER DISCHARGE PERMIT ISSUED TO OAK RIDGE POTW SHOWING MONITORING AND REPORTING REQUIREMENTS

APPENDIX C - REGIONAL DEMOGRAPHY/SOCIOECONOMICS ACRONYMS

ORR Oak Ridge Reservation

ROI Region of Influence

REGIONAL DEMOGRAPHY/SOCIOECONOMICS

The first step in providing background for demographic and socioeconomic impact analysis is to define a Region of Influence (ROI) for the proposed and alternative actions. All activity related to the alternatives would take place either within the city of Oak Ridge or on the Oak Ridge Reservation (ORR), both of which are located within Anderson and Roane Counties, Tennessee. Although the site of activities represents a small portion of the entire two-county area, the actions taking place could have repercussions for the whole area's economy. Therefore, it was assumed that Anderson and Roane Counties were the appropriate definition for the ROI.

Demographics

Oak Ridge is located in the east central section of Tennessee, ~32 km (20 miles) west of Knoxville, Tennessee. Oak Ridge includes portions of both Anderson and Roane Counties. There were 27,310 people living in Oak Ridge in 1990, as reported by the U.S. Bureau of the Census (Table C.1; all tables are presented at the end of Appendix C). In general, the population in Oak Ridge is older than the population in the ROI, which is in turn generally older than the population in Tennessee (Table C.1). The largest share of the population is in the "baby boom" cohort (between 25 and 54 years of age), with an estimated 41.6% of the ROI population in 1990. The Oak Ridge population declined slightly over the period 1980 to 1990, as did the population for the ROI (Table C.2). This decline was in contrast to the modest growth recorded for the state over the same period. The Oak Ridge population represented 23.6% of the total ROI population in 1990.

Housing

Tables C.2 and C.3 report summary statistics on housing in Oak Ridge, Anderson, and Roane Counties, the ROI, and Tennessee. As shown in Table C.2, the total number of housing units has grown over the last decade for both the city and the counties. The number of housing units has increased at an average annual rate of 1.0% in Oak Ridge from 1980 to 1990, which is less than the average annual growth of 1.3% reported for Anderson County, 1.1% for the ROI, and 1.5% for the state. Average household size in Oak Ridge and the ROI was slightly lower than the state in both 1980 and 1990.

Table C.3 shows that most of the housing units in Oak Ridge in 1990 were single-family homes (70.4%), followed by multifamily units (29.1%), and mobile homes (0.5%). This distribution differs from that for the ROI, which shows a slightly higher share of units in the single-family (72.2%) and mobile home (12.7%) categories but a lower share of multifamily units (15.1%). Vacancy rates for homeowner housing units were the same for Oak Ridge and the ROI in 1990; however, this vacancy rate was higher at the state level. The pattern for rental vacancy rates was slightly different. The rental vacancy rate was higher for Oak Ridge (14.5%) than for either the ROI (9.5%) or the state (9.6%).

Employment

Tables C.4 and C.5 provide a background on employment and the number of building establishments in the ROI. There were a total of 71,046 people employed in the ROI in 1992 (Table C.4). Of this total, 60,737 (85.5%) were employed in the nonfarm, private sector; 9,101 (12.8%) were employed by government enterprises; and 1,208 (1.7%) were employed on farms. The services sector accounted for the most employment in 1992 (34.5%), followed by manufacturing (25.3%), retail trade (12.4%), and state and local

governments (8.8%). The greatest average annual growth in employment between 1970 and 1992 occurred in the services sector (6.7%), followed by construction (6.4%), agricultural services (5.8%), and transportation and public utilities (3.6%). The biggest employment declines over the same 22-year period occurred in mining (-5.4%), manufacturing (-0.5%), and military.

Table C.5 shows the number of establishments by industry sector in Anderson and Roane Counties and the ROI in 1980 and 1990. The most 1990 establishments were reported in services (841), followed by retail trade (607), finance, insurance, and real estate (170), and construction (166). The fastest growth in establishments between 1980 and 1990 was experienced by agricultural services (7.2%), followed by services (5.4%), construction (4.0%), and manufacturing (3.8%).

Earnings and Income

Table C.6 shows the breakdowns in average annual earnings per employee by sector. The highest earnings in 1992 were for federal civilian employees ($44,935), followed by manufacturing ($40,611), transportation and public utilities ($31,195), services ($30,024), and wholesale trade ($27,097). The greatest average annual growth in average earnings (in current or nominal dollars) between 1970 and 1992 is shown to be in services (9.1%), followed by military (8.3%), transportation and public utilities (6.9%), and manufacturing (6.8%). Because the overall growth in the consumer price index over the 22-year period averaged 6.0%, these industries all registered growth in real average earnings per employee during this period.

Table C.7 shows per capita income trends for the ROI from 1980 to 1992. It shows values in both nominal dollars and constant dollars (estimated using the consumer price index with a 1982-1984 base year). Per capita income increased an average annual rate of 6.1% in the ROI over the dozen years; however, the real rate of increase averaged only 1.5% per year.

References

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Table C.1. Distribution of population by age cohort for the city of Oak Ridge, Anderson and Roane Counties, and Tennessee, 1990

	Population (number of people)					Cohort share (%)		
Age cohort	Oak Ridge	Anderson County	Roane County	ROI[a]	Tennessee	Oak Ridge	ROI[a]	Tennessee
Under 5	1,488	4,206	2,666	6,872	333,415	5.4	6.0	6.8
5 - 17	4,634	12,128	8,441	20,569	883,189	17.0	17.8	18.1
18 - 24	1,957	5,909	4,203	10,112	527,655	7.2	8.8	10.8
25 - 54	11,044	28,518	19,591	48,109	2,079,519	40.5	41.6	42.7
55 - 64	3,150	7,004	5,271	12,275	434,589	11.5	10.6	8.9
65 & Over	5,037	10,485	7,055	17,540	618,818	18.4	15.2	12.7
TOTAL	27,310	68,250	47,227	115,477	4,877,185	100.0	100.0	100.0

Source: U.S. Bureau of the Census, 1991. *1990 Census of Population and Housing, Summary Population and Housing Characteristics, Tennessee*, 1990 CPH-1-44, August.

[a] ROI defined as the total for Anderson and Roane Counties.

Table C.2. Population and housing trends in the city of Oak Ridge, Anderson and Roane Counties, and Tennessee, 1980-1990

	Population (people)			Housing (units)			Occupied units			Avg. household size		
Region	1980	1990	%Cng.	1980	1990	%Cng.	1980	1990	%Cng.	1980	1990	%Cng.
Oak Ridge	27,662	27,310	-0.1%	11,487	14,904	2.6%	11,021	11,783	0.7%	2.51	2.32	-0.8%
Anderson Co.	67,346	68,250	0.1%	25,849	29,323	1.3%	24,616	27,384	1.1%	2.74	2.49	-1.0%
Roane Co.	48,425	47,227	-0.3%	18,732	20,334	0.8%	17,078	18,453	0.8%	2.84	2.56	-1.0%
ROI[a]	115,771	115,477	0.0%	44,581	49,657	1.1%	41,694	45,837	1.0%	2.78	2.52	-1.0%
Tennessee	4,591,120	4,877,185	0.6%	1,747,422	2,026,067	1.5%	1,618,505	1,853,725	1.4%	2.84	2.63	-0.8%

Sources: U.S. Bureau of the Census, 1982a. *1980 Census of Housing, Volume 1, Characteristics of Housing Units, Chapter A, General Housing Characteristics, Part 44, Tennessee*, HC80-1-A44, August; U.S. Bureau of the Census, 1991. *1990 Census of Population and Housing, Summary Population and Housing Characteristics, Tennessee*, 1990 CPH-1-44, August.

a ROI defined as the total in Anderson and Roane Counties.

Note: %Cng. is the average annual compound percent change.

Table C.3. Housing characteristics for the city of Oak Ridge, Anderson and Roane Counties, and Tennessee, 1990

Region	Single family (units)	(%)	Multifamily (units)	(%)	Mobile homes (units)	(%)	Vacancy rates (%) Owners	Renters
Oak Ridge	8,867	70.4	3,665	29.1	60	0.5	1.2	14.5
Anderson Co.	20,688	70.6	5,375	18.3	3,260	11.1	1.1	9.3
Roane Co.	15,174	74.6	2,119	10.4	3,041	15.0	1.4	9.9
ROI[a]	35,862	72.2	7,494	15.1	6,301	12.7	1.2	9.5
TOTAL	1,713,523	73.7	405,100	17.4	207,444	8.9	2.1	9.6

Source: U.S. Bureau of the Census, 1991. *1990 Census of Population and Housing, Summary Population and Housing Characteristics, Tennessee*, 1990 CPH-1-44, August.

a ROI defined as the total for Anderson and Roane Counties.

Note: Percent by housing type reflects share of total housing within the region.

Table C.4. Distribution of employment in the ROIa, 1970, 1980, 1990 and 1992

Employment sector	1970	1980	1990	1992	Average annual growth (%) 1970-1980	1980-1990	1990-1992	1970-1992
FARMING	940	1,244	1,231	1,208	2.8	-0.1	-0.9	1.1
PRIVATE SECTOR	34,367	44,371	54,720	60,737	2.6	2.1	5.4	2.6
Agricultural services	84	119	228	292	3.5	6.7	13.2	5.8
Mining	769	732	364	241[b]	-0.5	-6.7	-18.7	-5.1
Construction	928	1,626	2,806	3,635	5.8	5.6	13.8	6.4
Manufacturing	19,913	23,660	17,966	17,985	1.7	-2.7	0.1	-0.5
Transportation and public utilities	856	1,075	1,468	1,865	2.3	3.2	12.7	3.6
Wholesale trade	518	1,095	952	1,083	7.8	-1.4	6.7	3.4
Retail trade	4,142	5,452	7,942	8,834[b]	2.8	3.8	5.5	3.5
Finance, insurance, and real estate	1,284	2,151	2,100	2,286	5.3	-0.2	4.3	2.7
Services	5,873	8,461	20,894	24,516[b]	3.7	9.5	8.3	6.7
GOVERNMENT SECTOR	6,773	6,483	8,942	9,101	-0.4	3.3	0.9	1.4
Federal, civilian	2,179	2,619	2,384	2,186	1.9	-0.9	-4.2	0.0

Military	671	2,645	697	658	14.7	-12.5	-2.8	-0.1
State and local	3,923	5,212	5,861	6,257	2.9	1.2	3.3	2.1
TOTAL	42,080	54,667	64,893	71,046	2.7	1.7	4.6	2.4

Source: Regional Economic Information System, Bureau of Economic Analysis, 1994a. *Full-Time Employees by Major Industry for Counties and Metropolitan Areas (Numbers of Jobs)*, Table CA25 (on diskette), May.

[a] Includes Anderson and Roane Counties.

[b] Estimated. Not reported because of disclosure issues. Assumes that retail trade accounts for the same share of total private employment as 1987; mining assumes same share of total private employment as 1991; services reflects the balance required to reach total for private employment.

Table C.5. Number of business establishments by county and sector in Anderson and Roane Counties, 1980 and 1990

	Anderson County		Roane County		ROI[a]		Avg. annual ROI growth 1980-90
Business sector	1980	1990	1980	1990	1980	1990	
Agricultural services	6	14	3	4	9	18	7.2%
Mining	29	10	7	3	36	13	-9.7%
Construction	68	125	44	41	112	166	4.0%
Manufacturing	71	107	29	38	100	145	3.8%
Transportation & pub. util.	40	56	20	17	60	73	2.0%
Wholesale trade	42	64	25	31	67	95	3.6%
Retail trade	339	388	215	219	554	607	0.9%
Finance, ins. & real estate	85	122	43	48	128	170	2.9%
Services	332	608	167	233	499	841	5.4%
Nonclassifiable	54	51	36	31	90	82	-0.9%
TOTAL	1,066	1,545	589	665	1,655	2,210	2.9%

Sources: U.S. Bureau of the Census, 1982b. *County Business Patterns, 1980, Tennessee*, CBP-80-44, May; U.S. Bureau of the Census, 1992. *County Business Patterns, 1990, Tennessee*, CBP-90-44, September.

[a] ROI is defined as the total for Anderson and Roane Counties.

Table C.6. Distribution of real average annual earnings in the ROI a, 1970, 1980, 1990 and 1992

					Average annual growth (%)			
Employment sector	1970	1980	1990	1992	1970-1980	1980-1990	1990-1992	1970-1992
FARMING	1,061	475	1,264	1,288	-7.7	10.3	0.9	0.9
PRIVATE SECTOR	7,623	17,100	26,555	29,917	8.4	4.5	6.1	6.4
Agricultural services	3,619	5,782	10,035	10,003	4.8	5.7	-0.2	4.7
Mining	10,257	41,643	23,088	22,548[b]	15.0	-5.7	-1.2	3.6
Construction	6,857	13,024	21,339	26,221	6.6	5.1	10.9	6.3
Manufacturing	9,516	22,026	35,099	40,611	8.8	4.8	7.6	6.8

Transportation and public utilities	7,172	14,314	26,766	31,195	7.2	6.5	8.0	6.9
Wholesale trade	6,807	13,711	24,561	27,097	7.3	6.0	5.0	6.5
Retail trade	3,981	8,019	12,923	14,557[b]	7.3	4.9	6.1	6.1
Finance, insurance, and real estate	4,466	6,967	11,560	13,483	4.5	5.2	8.0	5.2
Services	4,431	11,365	26,914	30,024[b]	9.9	9.0	5.6	9.1
GOVERNMENT SECTOR	6,855	21,098	25,182	26,453	11.9	1.8	2.5	6.3
Federal, civilian	11,166	29,515	39,687	44,935	10.2	3.0	6.4	6.5
Military	1,192	595	6,495	6,947	-6.7	27.0	3.4	8.3
State and local	5,429	11,110	21,504	22,528	7.4	6.8	2.4	6.7
TOTAL	7,352	16,392	25,886	28,986	8.3	4.7	5.8	6.4

Source: Regional Economic Information System, Bureau of Economic Analysis, 1994a. *Full-Time Employees by Major Industry for Counties and Metropolitan Areas (Numbers of Jobs)*, Table CA25 (on diskette), May.

[a]Includes Anderson and Roane Counties.

[b]Estimated. Not reported because of disclosure issues. Assumes that Retail trade accounts for the same share of total private earnings as 1987; services reflects the balance required to reach total for private employment; Mining accounts for the same share of total private earnings as 1991.

Table C.7. Trends in population and per capita income for the ROI[a], 1980 to 1992

Year	Population (# people)	Per capita income ($)	Average annual growth (%)	Real per capita income (1982-84=100)[b]	Average annual growth (%)
1980	116.0	8,642		10,488	
1981	115.9	9,449	9.3	10,395	-0.09
1982	115.9	10,042	6.3	10,406	0.1
1983	116.2	10,473	4.3	10,515	1.0
1984	116.2	11,156	6.5	10,738	2.1
1985	115.9	11,568	3.7	10,751	0.1
1986	114.8	12,263	6.0	11,189	4.1
1987	115.0	12,737	3.9	11,212	0.2
1988	115.3	13,814	8.5	11,677	4.1
1989	115.3	14,844	7.5	11,971	2.5
1990	115.6	15,444	4.0	11,817	-1.3
1991	117.0	16,351	5.9	12,005	1.6
1992	118.6	17,548	7.3	12,507	4.2
			Average Annual Growth Rate		
1980-1992	0.2%	6.1%		1.5%	

Source: Regional Economic Information System, Bureau of the Economic Analysis 1994b. *Personal Income by Major*

Source and Earnings by Industry for Counties and Metropolitan Areas (Thousands of Dollars), Table C45 (on diskette), May.

a Includes Anderson and Roane Counties.

[b] Converted into constant dollars using the consumer price index with a 1982-1984 base year, as reported in the U.S. Bureau of the Census, 1993. *Statistical Abstract of the United States, 1993*, 113th Edition, Table 756, p. 482.

APPENDIX D - HUMAN HEALTH RISK ASSESSMENT ACRONYMS

COC constituent of concern

CSF cancer slope factor

DOE U.S. Department of Energy

EA environmental assessment

EPA U.S. Environmental Protection Agency

HEAST Health Effects Assessment Summary Tables

HI hazard index

HQ hazard quotient

IRIS Integrated Risk Information System

LET linear energy transfer

LOAEL Lowest Observed Adverse Effect Level

NCP National Oil and Hazardous Substances Pollution Contingency Plan

NOAEL No Observed Adverse Effect Level

NRC National Research Council

ORNL Oak Ridge National Laboratory

ORR Oak Ridge Reservation

POTW Publicly Owned Treatment Works

RESRAD Residual Radioactivity computer model

RfC reference concentration

RfD reference dose

TDEC Tennessee Department of Environment and Conservation

1. HUMAN HEALTH RISK ASSESSMENT

1.1 INTRODUCTION

This appendix presents a human health risk assessment and is provided as a component of the environmental assessment (EA) for the U.S. Department of Energy (DOE) action to manage sewage sludge by land application on federal land. The ongoing land application operation, regulated by the state of Tennessee under U.S. Environmental Protection Agency (EPA) authority, is not part of the proposed action described in the EA. No human health risk evaluation exists for the ongoing operation; therefore, this risk evaluation of the ongoing sludge management practice is presented as an appendix to the EA.

Municipal sewage sludge is regulated by EPA under the authority of the Clean Water Act. EPA has delegated authority for local sludge management to the Tennessee Department of Environment and Conservation (TDEC), which has responsibility for compliance. However, the city of Oak Ridge must still comply with 40 *CFR* 503 regulations and report to the EPA Region IV annually.

The city of Oak Ridge has been applying sanitary sewage sludge to selected sites on the Oak Ridge Reservation (ORR) since 1983. The Oak Ridge Y-12 Plant is a standard industrial customer of the city of Oak Ridge. The Y-12 Plant is permitted to discharge sanitary sewage to the city, under the city's industrial pretreatment charter, with prescribed sanitary sewage discharge limits and restrictions similar to those of other industrial sewage generators located in the city. Final management of the treated sludge is by land application on federal land.

In addition to the Oak Ridge Y-12 Plant, which is a DOE facility that uses radioactive materials, there are several other state of Tennessee-licensed industrial facilities that also release radioactive materials into the Oak Ridge sanitary sewer system (e.g., American Ecology Recycle Center, Scientific Ecology Group, Manufacturing Sciences Corporation). With certain exceptions for patients of the local hospital, all facilities must meet the same acceptance criteria as other industrial users of the city's sewage treatment plant. In addition to radioactive materials, small quantities of inorganic compounds may also be released to the sewer. Sanitary sewage sludge also contains high concentrations of human pathogens. Bacterial, viral, parasitic, and fungal pathogens in municipal sewage sludge have been identified as potential hazards to human health (WHO 1981; Kowal 1982,1985). EPA has evaluated the risk from exposure to pathogens in land-applied sludge separately (EPA 1988, 1989a) and determined that the risk of exposure to pathogens in sludge-amended soils is minimal.

During the treatment process, constituents may become concentrated in the sludge. The health effects of exposure to sludge containing low levels of radionuclides or chemicals need to be estimated in order to evaluate the safety of the current practice. Therefore, risks associated with exposure to low levels of radionuclides and chemicals in sanitary sewage sludge are addressed in this appendix.

This risk assessment has been performed in accordance with current risk assessment guidance provided by the EPA including: *Risk Assessment Guidance for Superfund: Volume I, Human Health Evaluation Manual (Part A)* (EPA 1989b), *Supplemental Guidance* (EPA 1991a), and *Exposure Factors Handbook* (EPA 1990).

The report organization is as follows. Section 1 provides an overview of the risk assessment process. Section 2, Identification of Constituents of Concern, describes the COCs that are evaluated in this risk assessment and their site-specific media concentrations. Section 3, Toxicity Assessment, describes the determination of toxicity or dose-response values for the COCs. Section 4, Exposure Assessment, identifies potential receptors and describes how potential exposure pathways were identified and exposure conditions were estimated. Section 5, Risk Characterization, combines the data generated in the Exposure Assessment with the data presented in the Toxicity Assessment to derive estimates of potential risk posed by COCs in sludge-amended soils. Section 6, Uncertainty Analysis, discusses the major sources of uncertainty associated with each step of the human health risk assessment process. Section 7 presents the Summary and Conclusions.

1.2 SITE-SPECIFIC RISK ASSESSMENT APPROACH

The purpose of this human health risk assessment is to evaluate the extent to which compounds present in the Publicly Owned Treatment Works (POTW) sewage sludge may potentially present a risk to human health, either during the application process or after blending with site soils. Quantitative estimates of potential carcinogenic and noncarcinogenic risks are made and presented for potential exposures associated with probable use of the land application site.

The predominant current and expected future land uses on the ORR are industry, forestry, environmental research, and agriculture. Nearly all workers are employed and located at the three major DOE industrial and research facilities [Oak Ridge National Laboratory (ORNL), Y-12 Plant, K-25 Site]; only a small percentage of work (environmental research, silviculture, and agriculture) is performed on the ORR outside of these facilities. Access is restricted on the entire ORR, including the three major facilities. All land application sites are within the ORR. The focus of this risk assessment is the evaluation of the potential risk to human health due to the presence of constituents in treated sewage sludge and ultimately in site soils at the land application sites. Because access is restricted at each of the locations, surface soils are not generally available for direct human contact by the general public.

Trained sludge workers would be present at the land application site during application of sewage sludge to soil. Exposure could occur during application; however, procedures are currently in place to limit exposure to workers during application. Theoretically, it is possible for a trespasser to have intermittent contact with the sludge-amended soils, although because of current access restrictions the potential for this exposure scenario to occur is limited. If it did occur, it is likely that it would be infrequent and that the exposure would be of short duration. Therefore, the only realistic potential exposure scenario for each of the land application sites is contact with sludge during the application process by a worker. However, to be conservative, it is assumed that a trespasser could contact constituents in soils. Both of these scenarios have been evaluated in the risk assessment.

There are no off-site residential receptors in the vicinity of the land application sites on the ORR; therefore, off-site impacts from land application of sludge have not been evaluated in this risk assessment.

Risk estimates for the two scenarios [on-site employee and trespasser (transient)] were made using default parameters provided by regulatory guidance to evaluate reasonable maximal exposure associated with land application sites.

1.3 RISK ASSESSMENT OVERVIEW

The risk assessment evaluates a single hypothetical land application site using the standard operating practices and receiving sanitary sludge that contains radionuclide and chemical concentrations that represent the measured sludge concentrations and soil concentrations at current land application sites. The approach and methodology used in this human health risk assessment are consistent with the guidance developed by the National Research Council (NRC). The NRC, established by the National Academy of Sciences to further scientific knowledge and to advise the federal government, developed the four-step paradigm for conducting health-based risk assessments (NRC 1983). This paradigm has been adopted by EPA as well as many other federal and state agencies. In accordance with the NRC recommendations, this risk assessment is organized into the following four steps:

1. Identification of Constituents of Concern (COCs)
2. Toxicity Assessment
3. Exposure Assessment
4. Risk Characterization

These four steps are described briefly below.

Identification of COCs. This step of the risk assessment process defines the COCs that are selected for more detailed evaluation in the remainder of the risk assessment. The data used to evaluate potential exposure are also presented in this section.

Toxicity Assessment. In the toxicity assessment, the relationship between the magnitude of exposure (dose) and the potential for occurrence of specific health effects (response) for each COC is evaluated. Both carcinogenic and noncarcinogenic effects are considered. The most current EPA-verified dose-response values are used when available.

Exposure Assessment. The objective of the exposure assessment is to evaluate the magnitude and frequency of potential exposure to COCs. Potentially exposed individuals, and the pathways by which they are potentially exposed, are identified based on the physical characteristics and uses of the site and surrounding area. The extent of a receptor's exposure is estimated by constructing "exposure scenarios" that describe the potential pathways of exposure to COCs and the activities and behaviors of individuals that might lead to contact with constituents in the environment.

Risk Characterization. In the risk characterization step, the results of the exposure assessment are combined with the results of the toxicity assessment to derive pathway-specific quantitative estimates of potential health risks. The estimates for each exposure pathway are then summed to give total risk estimates. Separate quantitative estimates of potential risk are derived for potentially carcinogenic effects and for noncarcinogenic effects.

2. IDENTIFICATION OF CONSTITUENTS OF CONCERN

Digested sludge that is to be applied to the land application areas is sampled and analyzed for organic, inorganic, heavy metal, and radionuclide compounds in an ongoing monitoring program based on state and federal requirements. Parameters such as pH, total percent solids, and percent volatile solids are monitored daily. Total gamma content is monitored each day that sludge is applied on the ORR, and quantitative radionuclide levels in sludge are measured weekly. Inorganic parameters such as nitrogen (ammonia, nitrate, nitrite, organic, and total nitrogen), potassium, phosphorus, and heavy metals are analyzed monthly. Organic compounds are analyzed in the digested sludge semiannually.

Many chemical and physical parameters monitor the efficacy of the sludge treatment system. For example, pH and total solids content allow treatment workers to judge whether the system is properly loaded or in danger of becoming too acid for effective microbial degradation. Similarly, measures of different forms of nitrogen monitor the degree to which the sludge is digested and the limits to which the resulting sludge can be spread on land and used as a fertilizer. These parameters are shown in Table D.1. While measurable and vital to the operation of the treatment system, these analytes are nutrients for beneficial use and are not COCs to be addressed in this risk assessment.

During the biological digestion of sludge, microorganisms use the organic compounds present for growth, producing carbon dioxide or methane as a by-product. Therefore, with a properly working treatment system, most organic constituents would be reduced below detectable limits. For example, analyses for 1994 show that of the organic chemicals that were tested for in composite samples, aroclor-1254, chlordane, 4,4-DDE, and dieldrin were each reported at or slightly above detection in a single composite sample. Because, as a whole, the digestion process is working properly and reduces organic compounds below detectable limits, organic compounds are not considered to be of concern in this risk assessment.

Digested sludge was sampled monthly in 1993 and 1994 for heavy metals as required by 40 *CFR* 503 regulations for the land application of sludge. Table D.2. shows the maximum detected metal levels during 1993 and 1994 and compares them with the concentration limits in 40 *CFR* 503.13. In all samples, the heavy metals content of the sludge is below statutory limits. However, because some heavy metals can accumulate in the soil and bioaccumulate in biota, it is a conservative assumption for this risk assessment to consider these metals of potential concern.

The city of Oak Ridge sludge contains radionuclides that are generated from a variety of domestic and industrial sources. Although there are no applicable regulatory limits governing radionuclide levels in sewage sludge, composite sludge samples are monitored daily and analyzed weekly for radionuclides. The average yearly radionuclide levels from 1988 to 1993 are shown in Table D.3. Because of the conservative approach for this risk assessment, radionuclides with half-lives longer than 2 months (see Table D.3 for half-lives) were considered to be potential COCs because of their ability to accumulate.

Although some pathogens tend to concentrate in sludge during wastewater treatment, most are inactivated during anaerobic digestion (Sopper 1993). Inactivation varies by pathogen type, but, in general, the success of a treatment process to significantly reduce pathogens (as defined in 40 *CFR* 257) depends on its retention time and creating an environment particularly hostile to pathogenic organisms (EPA 1991b, 1991c, 1992b). For example, ova and cysts of parasites, which are more resistant to inactivation, may be reduced by only about 30-40% during anaerobic digestion (EPA 1991c); but poliovirus can be 98.8% inactivated (Bertucci et al. 1977) and bacteria typically reduced by 1-2 orders of magnitude (Pedersen 1981) [i.e., 5000 organisms reduced to 500 (1 order of magnitude) or even 50 (2 orders of magnitude)]. Application of sludge on plants and on the soil surface exposes remaining pathogens to desiccation and sunlight, further reducing the pathogens' survival rate.

Table D.1. Maximum concentrations of inorganic constituents in city of Oak Ridge POTW sewage sludge (1993-1994)

Inorganic parameter	Sampling frequency	Highest level detected in sludge in 1993 (mg/kg)	Highest level detected in sludge in 1994 (mg/kg)
Ammonia-nitrogen[a]	Monthly	60,000.00	30,000.00
Manganese	Monthly	1,260.0	1,710.0
Nitrate nitrogen[a]	Monthly	40.2	269.0
Nitrite nitrogen[a]	Monthly	8.8	30.7
Organic nitrogen	Monthly	40,000.0	49,800.0
pH	Daily	7.7	8.1
Potassium	Monthly	5,960.0	5410.0
Phosphorus	Monthly	36,200.0	36,800.0
Total Kjeldahl nitrogen[a]	Monthly	94,100.0	77,200.0
Total nitrogen[b]	Monthly	94,111.8	77,223.7
Total solids %	Daily	3.2%	3.3%
Volatile solids (% or TS)	Daily	63%	62%

Source: City of Oak Ridge 1994, 1995.

[a] These parameters are required to be sampled annually by National Pollutant Discharge Elimination System permit #TN0024155. Reporting of quantitative data is required, but limits are not specified.

[b] Total nitrogen represents the sum of total Kjeldahl and nitrate nitrogen.

Table D.2. Maximum concentrations of heavy metal constituents in city of Oak Ridge POTW sewage sludge (1993-1994) vs 40 CFR 503.13 ceiling concentration limits

Heavy metal	Highest level detected in sludge (mg/kg dry wt) in 1993	Highest level detected in sludge (mg/kg dry wt) in 1994	40 *CFR* 503.13 Ceiling concentration limits (mg/kg dry wt)	Highest level detected as a percentage of regulatory ceiling
Arsenic	25.1	10	75	33%
Cadmium	15.1	18	85	21%
Chromium[a]	185	194	3000	6%
Copper	544	490	4300	13%

Lead	95	128	840	15%
Mercury	16.2	9	57	28%
Molybdenum	33.8	24	75	45%
Nickel	51	46	420	12%
Selenium	20.9	10	100	21%
Zinc	2070	1840	7500	27%

Source: City of Oak Ridge 1994, 1995.

[a] 40 *CFR* 503 limits for chromium have been excised by the EPA until further notice.

Table D.3. Historical radiological characterization of Oak Ridge sanitary sewage sludge (selected radionuclides)

		Average concentration, pCi/g dry weight					
Radionuclide	Half-life	1988	1989	1990	1991	1992	1993
Beryllium-7	53.6 days	1.2	1.5	1.7	1.6	1.3	1.7
Potassium-40	1.28×10^9 years	7.0	6.8	7.2	5.9	5.1	5.8
Cobalt-60	5.27 years	5.3	2.5	3.3	0.9	0.8	0.6
Iodine-131	8.04 days	6.8	8.5	5.9	9.7	17	42
Cesium-137	30.2 years	2.0	1.3	2.7	1.4	0.5	0.6
Radium-228	5.8 years	0.6	0.9	1.2	0.7	0.7	0.9
Uranium-total	4.5×10^9 years	140	50	30	25	23	13[a]
Uranium-235 assay		0.32%	0.51%	0.71%	0.80%	0.90%	0.8%[b]

Source: Adapted from Stephenson 1994d.

[a] Based on gamma spectroscopy; prior year total uranium by neutron activation, uranium-235 assay by mass spectroscopy.

[b] Sources of radionuclides in sewage sludge include naturally occurring radionuclides, medical radionuclides (Iodine-131), and nuclear facilities with state-permitted radionuclide discharges.

Reliable, EPA-approved risk assessment models are not available for quantifying human health risk from pathogens, but sludge application operator evidence and literature research show minimal risk from pathogens. Studies indicate that under EPA-approved sludge application practices, pathogens are not a health risk (Kowal 1982; EPA 1988, 1989a, 1991b, 1991c, 1992b; Sopper 1993). Land application of anaerobically digested sludges known to contain Salmonellae were found to present no apparent health risk to farm families when used in agricultural applications (Ottolenghi and Hamparian 1987). Cows grazed on anaerobically digested sludge-treated forage showed no bacterial, viral, or fungal infections in live animals or at necropsy, and incidence of intestinal parasites was the same in experimental and control cattle (Fitzgerald 1979). Land application of Chicago sludge on 6,000 ha resulted in no significant public health problems (Sedita et al. 1977) Reddy et al. (1985) also noted no significant health risk to humans or animals at sludge application rates of 2-10 metric tons/ha.

In summary, because of their potential to accumulate, heavy metals and radionuclides are potential COCs for evaluation of human health risk. Organics, inorganic nutrients, and pathogens are not considered COCs in this human health risk assessment.

3. TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to identify the types of adverse health effects a COC may cause and to define the relationship between the dose of a COC and the likelihood or magnitude of an adverse effect (response). Adverse effects are characterized by EPA as carcinogenic or "noncarcinogenic," (i.e., potential effects other than cancer). Dose-response relationships are defined by EPA for oral exposure and for exposure by inhalation. Combining the results of the dose-response assessment with information on the magnitude of potential human exposure provides an estimate, usually very conservative, of potential risk.

Section 3.1 describes EPA's approach for developing noncarcinogenic dose-response values. Section 3.2 describes the carcinogenic dose-response relationships developed by EPA. Section 3.3 presents a discussion of radiological dose-response values and Section 3.4 discusses chemicals for which no EPA toxicity values are available. Sources of the published dose-response values used in this risk assessment include EPA's Integrated Risk Information System (IRIS) (EPA 1994a) and the Health Effects Assessment Summary Tables (HEAST) (EPA 1994b).

3.1 NONCARCINOGENIC DOSE-RESPONSE

Compounds with known or potential noncarcinogenic effects are assumed to have a dose below which no adverse effect occurs or, conversely, above which an adverse effect may be seen. This dose is the threshold dose. The threshold dose is called a No Observed Adverse Effect Level (NOAEL). The lowest dose at which an adverse effect occurs is called a Lowest Observed Adverse Effect Level (LOAEL). By applying uncertainty factors to the NOAEL or the LOAEL, References Doses (RfDs) for chronic exposures to chemicals with noncarcinogenic effects have been developed by EPA (1994a, 1994b). The uncertainty factors account for uncertainties associated with the dose-response relationship such as the effects of using an animal study to derive a human dose-response value, extrapolating from high to low doses, and evaluating sensitive subpopulations. Generally, a 10-fold factor is used to account for each of these uncertainties; thus, the total uncertainty factor can range from 10 to 10,000. In addition, an uncertainty factor or modifying factor of up to 10 can be used to account for "inadequacies in the database." For chemicals with noncarcinogenic effects, an RfD provides reasonable certainty that no noncarcinogenic health effects are expected to occur even if daily exposures were to occur at the RfD level for a lifetime. RfDs and exposure doses are expressed in units of milligrams of chemical per kilogram body weight per day (mg/kg-day).

Table D.4. summarizes the dose-response information for the COCs with potential noncarcinogenic effects for the oral and inhalation routes of exposure. For each chemical, the dose-response value, and the reference for the dose-response value is presented. In addition, the target organ and critical effect upon which the dose-response value is based are also presented for each chemical.

In accordance with EPA National Center for Environmental Assessment policy, only chemicals with EPA-verifiable Reference Concentrations (RfCs) have been evaluated for noncarcinogenic effects following inhalation exposures. Dose-response values for the inhalation route of exposure are provided by the EPA as RfCs, expressed as milligrams of compound per cubic meter of air (mg/m3). In order to use these dose-response values to calculate an average daily exposure dose, the RfCs are converted to RfDs, expressed as the corresponding inhaled dose in mg/kg-day. The conversion from RfC to RfD follows the formula cited in HEAST (EPA 1994b):

$$\text{RfC (mg/m}^3\text{) x (1/70 kg) x (20 m}^3\text{/day) = RfD (mg/kg-day)}$$

Table D.4. Dose-response data for COCs with potential noncarcinogenic effects

Compound	CAS[a]	Inhalation RfD (mg/kg-day)	Reference (last verified)	Oral RfD(mg/kg-	Reference(last verified)	Target organ system

				day)		
Arsenic	7440382	NA[b]	—	3.0E-4	IRIS (7/95)	Skin; keratosis
Cadmium	7440439	NA	—	5.0E-4	IRIS (7/95)	[c]
Chromium(as Cr-VI)	7440473	NA	—	5.0E-3	IRIS (7/95)	No adverse effects observed
Copper	7440508	NA	—	3.71E-2	HEAST (11/95)	Gastrointestinal
Lead	7439921	NA	—	NA	—	CNS[d]; blood
Mercury	7439976	$8.57E^{-5}$	IRIS (7/95)	NA	—	Kidney effects
Molybdenum	7439987	NA	—	5.0E-3	IRIS (7/95)	Urine; joints; blood
Nickel	7440020	NA	—	2.0E-2	IRIS (7/95)	Decreased body and organ weight
Selenium	7782492	NA	—	5.0E-3	IRIS (7/95)	Whole body; selenosis
Zinc	7440666	NA	—	3.0E-1	IRIS (7/95)	Blood; anemia

[a] Chemical Abstracts Service Registry Number.

[b] NA = Not available; inhalation RfD is not listed in IRIS database or HEAST tables (EPA 1994b).

[c] The oral RfD for cadmium was derived by EPA using a pharmacokinetic model assuming 5% absorption from water and 2.5% absorption from food/soil.

[d] CNS = central nervous system.

3.2 CARCINOGENIC DOSE-RESPONSE

The underlying assumption of regulatory risk assessment for compounds with known or assumed potential carcinogenic effects is that no threshold dose exists. Thus, the characterization assumes that there is some finite level of risk associated with each nonzero dose. The EPA methodology is to extrapolate dose-response relationships observed at the relatively high doses used in animal studies to the low dose levels encountered by humans in environmental situations. The mathematical models assume no threshold and use both animal and human data to develop a potency estimate for a given compound. The potency estimate, called a cancer slope factor (CSF) is expressed in units of $(mg/kg\text{-}day)^{-1}$.

Table D.5. summarizes the oral and inhalation dose-response information developed by EPA for potentially carcinogenic COCs identified for this assessment. For each chemical, the CSF and its reference are provided.

3.3 RADIATION TOXICITY

The potential health effects associated with exposure to radionuclides at the land application sites are due to low-level ionizing alpha, beta, and gamma radiation emitted by the radionuclides in sanitary sewage sludge. The primary effects include an increase in the occurrence of cancer in irradiated individuals and possible genetic effects that may occur in future generations. The risk of serious genetic effects is much lower than the risk of cancer induction (EPA 1989b). Therefore, genetic effects are not the focus of this toxicity assessment, and radiological risks are evaluated only with respect to incremental cancer probabilities per EPA guidance (EPA 1989b).

The toxicity of the various radionuclides found in sludge is based on:

- the types and energies of radiation they emit;
- the biological importance of the organs/tissues being irradiated;
- the radiological sensitivity of the organs/tissues being irradiated; and
- for internal exposure only, metabolic behavior in the body and biological retention characteristics in the body.

Radiation-induced health effects for humans have been confirmed only at relatively high doses or high dose rates with large populations. Exposure to a high dose of radiation (e.g., a thousand times the average annual background dose rate) during a short period of time (a few hours) produces detrimental effects in all the organs and systems of the body. For low doses, health effects are presumed to occur but can only be estimated statistically. Risk estimates are strictly applicable to large populations, because the appearance of health effects after an exposure is a chance event. For purposes of radiological impact assessment, the health effects are measured by cancer incidence in the exposed population. However, risk estimates in the low-dose range are uncertain because of extrapolation from high doses and because of assumptions made on dose-effect relationships and the underlying mechanisms of carcinogenesis.

Table D.5. Dose-response data for COCs with potential carcinogenic effects

Compound	CAS[a]	Weight of evidence[b]	Oral slope factor (mg/kg-day)$^{-1}$	Reference (last verified)	Inhalation slope factor(mg/kg-day)	Reference (last verified)
Arsenic	7440382	A	1.5E+0	IRIS (7/95)	1.51E+1	IRIS (7/95)
Cadmium	7440439	B1	NA[c]	—	6.3E+0	IRIS (7/95)
Chromium (as Cr-VI)	7440473	A	NA	—	4.2E+1	IRIS (7/95)
Copper	7440508	D	NA	—	NA	HEAST (11/95)
Lead	7439921	B2	NA	—	NA	—
Mercury	7439976	D	NA	—	NA	HEAST (11/95)
Molybdenum	7439987	—	NA	—	NA	IRIS (7/95)
Nickel	7440020	A	NA	—	NA	IRIS (7/95)
Selenium	7782492	D	NA	—	NA	IRIS (7/95)
Zinc	7440666	D	NA	—	NA	IRIS (7/95)

[a]Chemical Abstracts Service Registry Number.

[b]Weight of Evidence Classifications:

A = Human carcinogen (sufficient evidence of carcinogenicity in humans)
B1= Probable human carcinogen (limited evidence of carcinogenicity in humans)
B2= Probable human carcinogen (sufficient evidence of carcinogenicity in animals, with inadequate or lack of evidence of carcinogenicity in humans)
C = Possible human carcinogen (limited evidence of carcinogenicity in animals, and inadequate or lack of evidence of human data)
D = Not classifiable as to human carcinogenicity

[c]NA = Not available; chemical is not listed in IRIS database or HEAST tables as a carcinogen (EPA 1994b).

Radiation effects in the exposed population cannot be readily identified because radiogenic cancers are indistinguishable from those resulting from other factors. Studies of populations chronically exposed to low-level radiation, such as those residing in regions of elevated natural background, have not shown consistent evidence of an associated increase in the risk of cancer.

Alpha, beta, and gamma radiations are released during the radioactive decay process. Each type of radiation differs in its physical properties and in its ability to induce damage to biological tissue. The BEIR IV report (NRC 1988) addresses the risk from alpha radiations. Alpha particles are an internal exposure hazard rather than an external hazard because they are unable to penetrate the dead skin cell layer of the body to reach living tissue. Within the body alpha particles are the most effective of the three types of radiation in damaging cells because they have high linear energy transfer (LET), (i.e., their energy is completely absorbed by tissue within a short distance). High LET radiation is more damaging to cells than low LET radiation. The BEIR V report (NRC 1990) addresses the risk from low LET radiation such as gamma and beta particles. Beta particles are primarily an internal hazard; however, in cases of external skin exposure, energetic beta particles can penetrate living skin cells, representing an external hazard as well. Beta particles deposit less energy to small volumes of tissue than alpha particles and, therefore, induce much less damage than alpha particles. Gamma radiation is primarily an external hazard because it can penetrate tissue and reach internal organs without being taken into the body.

EPA has developed guidance for radiological risk assessment consistent with existing guidance for assessing chemical carcinogenic risks (CSFs per unit intake) (EPA 1989b). Table D.6 summarizes potency factors used in the calculation of potential risk from exposure to radionuclides.

Table D.6 Radionuclide potency factors.

Radionuclide	External radiation slope factor 1/year per pCi/g	Inhalation slope factor 1/pCi	Ingestion slope factor 1/pCi
Cobalt - 60	9.8E-6	6.9E-11	1.9E-11
Cesium - 137 + D	2.1E-6	1.9E-11	3.2E-11
Potassium - 40	6.1E-7	7.5E-12	1.3E-11
Radium - 228 + D	6.7E-6	2.7E-9	3.0E-10
Uranium - 235 + D	2.7E-7	1.3E-8	4.7E-11
Uranium - 238 + D	5.7E-8	1.2E-8	6.2E-11

Source: HEAST (EPA 1994b).

3.4 CHEMICALS FOR WHICH EPA TOXICITY VALUES ARE NOT AVAILABLE

Because of the uncertainties in the relationship between exposure to lead and biological effects (dose-response), it is unclear whether the noncarcinogenic effects of lead exhibit a threshold response. Therefore, an RfD for lead is not available. Lead exposure health effects of most concern are impaired mental and physical development in young children. Because most human health effects data are based on blood lead (Pb) concentration, EPA has developed a quantitative method for estimating detrimental environmental lead levels in children using an uptake biokinetic model. Several EPA regional and state models exist to address situations where adults are exposed. Because the interim soil cleanup level of 400 ppm for residential sites and 1000 ppm for industrial sites recommended by Office of Emergency and Remedial Response directive 9355.4-12 (EPA 1994c) is so much greater than the maximum measured concentration in sludge or soil, an evaluation of blood lead levels was not done in this assessment.

4. EXPOSURE ASSESSMENT

4.1 IDENTIFICATION OF POTENTIAL RECEPTORS

Receptors considered for exposure to the sludge include an employee who would load the sludge and spread it on the application areas and a transient who would be incidentally exposed to the soil shortly after sludge application. Currently, an employee of the city of Oak Ridge POTW applies sludge to the designated soil areas on a daily basis and is considered as the maximally exposed individual. Although there is restricted access to the application areas on the ORR, a transient scenario was considered. Land use at the ORR is anticipated to remain industrial; therefore, a hypothetical receptor residing on an application site in the future was not considered in this assessment.

4.2 IDENTIFICATION OF EXPOSURE PATHWAYS

A complete exposure pathway consists of the following four elements: (1) a source and mechanism of contaminant release to the environment, (2) an environmental transport mechanism for the released contaminants, (3) a point of human contact with the contaminated medium, and (4) a route of entry for the contaminant into the human receptor at the exposure point. The sludge itself can be considered the exposure point without a release to any other medium. The soil, as the receiving medium, can also be an exposure point following sludge application. An integration of the source, its release, fate and transport mechanisms, exposure points, and exposure routes is evaluated for complete exposure pathways. If any of these elements is missing, the pathway is incomplete and will not be considered further in this risk evaluation.

For the city of Oak Ridge POTW sludge, the sludge itself is the source of the contamination. It can be released into the air during application procedures, and it is released into the soil as it is applied. Potential exposure routes to human receptors include inhalation of suspended sludge particles, incidental ingestion of sludge, and dermal contact when handling contaminated equipment or soil. Because of uncertainties associated with the quantification of dermal exposure (EPA 1992a) and because dermal exposure is considered to be less than that by direct ingestion for the constituents included in this risk assessment, only inhalation and ingestion pathways and external radiation are considered quantitatively in this assessment. The city uses a gamma counting system to screen sludge each day that material is hauled to the ORR for application to ensure that external exposures are below the approved action limits. Therefore, external exposure to radionuclides in sludge is not evaluated for the worker. Because radionuclides can be concentrated in soil over time, external exposure to gamma radiation from the soil is included for evaluation of the trespasser.

4.3 MEDIA EXPOSURE CONCENTRATIONS

Radionuclide and chemical exposure point concentrations in sludge are shown in Table D.7. Exposure point concentrations in sludge and air. Maximum and average measured concentrations from sampling events in 1994 were used in the risk assessment. Mean and maximum radionuclide and chemical air concentrations (pCi/m^3 or mg/m^3) were conservatively estimated from the sludge concentration by:

$$Cair = PL * Csoil * CF$$

where

PL = Particulate loading (50 g/m^3),

Csoil = Concentration of chemical or radionuclide in soil (mg/kg or pCi/g), and

CF = Conversion factor (1E-9 kg/ g or 1E-6 g/ g).

Table D.7. Exposure point concentrations in sludge and air

Constituent	Mean sludge concentration	Mean air concentration	Maximum sludge concentration	Maximum air concentration
		Radionuclides		
	pCi/g	pCi/m^3	pCi/g	pCi/m^3
Cobalt-60	0.18	9.0E-6	0.70	3.5E-5
Cesium-137	0.32	1.6E-5	0.47	2.4E-5
Potassium-40	5.06	2.5E-4	48.55	2.4E-3
Radium-228	0.79	4.0E-5	1.30	6.5E-5
Uranium-235	0.49	2.5E-5	0.94	4.7E-5
Uranium-238	12.39	6.2E-4	25.27	1.3E-3
		Chemicals		
	mg/kg	mg/m^3	mg/kg	mg/m^3
Arsenic	5.44	2.7E-7	10	5.0E-7
Cadmium	10.06	5.0E-7	18	9.0E-7
Chromium	148.55	7.4E-6	194	9.7E-6
Copper	458.81	2.3E-5	490	2.5E-5
Lead	72.52	3.6E-6	128	6.4E-6
Mercury	8.6	4.3E-7	9	4.5E-7
Nickel	38.84	1.9E-6	46	2.3E-6
Selenium	6.95	3.5E-7	10	5.0E-7
Zinc	1685	8.4E-5	1840	9.2E-5

It is conservatively assumed that air particulates during application are equal to the National Ambient Air Quality

Standard for the annual average respirable portion (PM10) of suspended particulate matter of 50 g/m^3. It is further assumed that 100% of the particulates have the same contaminant concentration as the soil value.

The 1994 measured maximum soil concentrations for radionuclides and chemicals and the estimated air concentrations are shown in Table D.8. Exposure point concentrations in soil and air. The values shown represent the soil exposure point concentrations used in evaluating potential exposure of a trespasser to accumulated concentrations in soil.

4.4 ESTIMATION OF POTENTIAL EXPOSURE DOSES

Chemical intake estimates are based on EPA methodology presented in *Risk Assessment Guidance for Superfund* (EPA 1989b) and related guidance (EPA 1991a). Radiological dose estimates were calculated using Residual Radioactivity (computer model) (RESRAD) in accordance with DOE Order 5400.5. For the worker, intakes and radiological doses were calculated for incidental sludge ingestion and inhalation of sludge particulates. The average and the maximum exposure point concentrations were used to provide a range of potential exposure.

Incidental ingestion of soil and inhalation of soil particulates as well as direct irradiation from the application site were evaluated for the trespasser. Maximum measured soil concentrations from 1994 were used.

The assumptions and calculations used to estimate chemical and radiological intakes for the receptors are shown in Table D.9. and Table D.10. Exposure time, frequency, and duration determine the total time that a receptor is exposed to the contaminant source. Exposure time is the number of hours per day that a receptor is present at a specific exposure point. Exposure frequency is the number of days per year that the exposure occurs, and exposure duration is the total number of years over which exposure occurs.

Based on current activity patterns, an employee is expected to be exposed to sludge through pumping, loading, or application activities for no more than 4 hours of each work day. An employee is assumed to work with sludge 250 days/year for 25 years (EPA 1989b). Because the application areas on the ORR have restricted access, trespassers were conservatively assumed to have exposure once a month for 1 hour each time over a 10-year period. Rates for incidental soil ingestion and inhalation are conservative based on maximal levels recommended in EPA guidance (EPA 1991a).

The radiological dose for both the employee exposed to maximal and average concentrations of radionuclides in sludge is 0.143 mrem/year and 0.067 mrem/year, respectively, (see Table D.11) well below a 10 mrem/year threshold, or an order of magnitude reduction of the primary public dose limit of 100 mrem/year from all sources of radiation as described in DOE Order 5400.5, Chap. II.

Table D.8. Exposure point concentrations in soil and air.

Constituent	Maximum soil concentration[a]	Maximum air concentration[b]
	Radionuclides	
	pCi/g	pCi/m3
Cobalt-60	0.64	3.2E-5
Cesium-137	0.71	3.6E-5
Potassium-40	ND	-
Radium-228	ND	-
Uranium-235	0.89	4.5E-5
Uranium-238	2.04	1.0E-4

Chemicals		
	mg/kg	mg/m3
Arsenic	6	3.0E-7
Cadmium	0.44	2.2E-8
Chromium	26.9	1.3E-6
Copper	39.8	2.0E-6
Lead	19	9.5E-7
Mercury	0.83	4.2E-8
Nickel	10	5.0E-7
Selenium	0.18	9.0E-9
Zinc	174	8.7E-6

[a] Maximum measured concentration from across all application sites.

[b] Estimated air concentration based on measured soil concentration.

Table D.9. Incidental sludge ingestion

	Value		
Parameter (unit)	Employee	Transient	Reference
Sludge ingestion rate (mg/day)	50	50	EPA 1991a
Fraction ingested from contaminated source (unitless)	0.5	1.0	Conservative judgment
Exposure frequency (day/year)	250		EPA 1989b, based on days employee works on site per year
		12	Conservative judgment
Exposure duration (years)	25		EPA 1989b, based on 90th percentile for employees
		10	Conservative judgment
Body weight (kg)	70	70	EPA 1989b, EPA 1991a, combined mean of male and female body weights
Carcinogen averaging time (days)	25,550	25,550	EPA 1990, equivalent to 70-year lifetime exposure at 365 days/year
Noncarcinogen averaging time (days)	9,125	3,650	EPA 1991a, exposure duration × 365 days/year

Equation for ingestion of chemicals in soil and sludge (EPA 1989a):

$$\text{Intake (mg/kg-d)} = \frac{C_S s \times IR_S \times CF \times FI \times EF \times ED}{BW \times AT}$$

where: C_S = chemical soil concentration in soil (mg/kg),

IR_S = soil ingestion rate (mg soil/day),

CF = conversion factor (10^{-6} kg/mg),

FI = fraction ingested from contaminated source (unitless),

EF = exposure frequency (days/year),

ED = exposure duration (year),

BW = body weight (kg), and

AT = averaging time (day).

Equation for ingestion of radionuclides in soil and sludge (Gilbert et al. 1989)

$$D_i = C_{soil,i} \times IR_S \times FI \times EF \times ED \times CF_m$$

where: D_i = intake from radionuclide i (pCi),

$C_{soil,i}$ = soil concentration of radionuclide i (pCi/g),

IRs = soil ingestion rate (mg/day),

FI = fraction ingested from the contaminated source (unitless),

EF = exposure frequency (days/year),

ED = exposure duration (year), and

CF_m = conversion factor, 10^{-3} g/mg.

Table D.10. Inhalation of particulates

Parameter (unit)	Value		Reference
	Employee	Transient	

Inhalation rate od airborne (m^3/hour)	20	20	EPA 1991a; Inhalation rates based on combination of rates for light, moderate, and heavy activity for an 8 hour workday
Exposure time outdoors (hours/day)	4	1	Site-specific observation (based on currewnt activity for employee). Professional judgement for transient.
Exposure frequency (day/year)	250	12	EPA 1989b, based on days employee works on site per year
Exposure duration (years)	25	10	EPA 1989b, based on 90th percentile for employees
Body weight (kg)	70	70	EPA 1989b
Carcinogen averaging time (days)	25,550	25,550	EPA 1990, equivalent to 70-year lifetime exposure at 365 days/year
Noncarcinogen averaging time (days)	9,125	3,650	EPA 1991a, exposure duration × 365 days/year

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Equation for ingestion of chemicals in soil and sludge (EPA 1989a):

$$\text{Intake (mg/kg-d)} = \frac{C_{air}s \text{ x IR x ET x EF x ED}}{\text{BW x AT}}$$

where:

C_Ss = contaminant concentration in the air (mg/m^3), derived from chemical concentration in soils,

IR = inhalation rate (m^3/hour),

ET = exposure time (hours/day),

FI = fraction ingested from contaminated source (unitless),

EF = exposure frequency (days/year),

ED = exposure duration (year),

BW = body weight (kg), and

AT = averaging time (day).

Equation for inhalation of particulates (radionuclides) (Gilbert et al. 1989)

$$D_i = C_{air,\,i} \times IR \times EF \times FT \times CF_t$$

where: D_i = intake from radionuclide i (pCi),

$C_{air,\,i}$ = air concentration of radionuclide i (pCi/m^3) (based on soil concentration)

EF = exposure frequency (days/year) (e.g., 4 hours/day x 250 days/year x days/24-hours = 41.7 days/year),

ED = exposure duration (year),

IR = inhalation rate (m^3/hour), and

CF_t = conversion factor, (24 hours a day)

5. RISK CHARACTERIZATION

5.1 METHODOLOGY

For the chemical assessment, risk is defined as the lifetime probability of cancer incidence for carcinogens and the estimate of exceeding toxic effect thresholds for noncarcinogens. For the radiological assessment, risk is defined as the lifetime probability of cancer morbidity and does not include genetic or noncarcinogenic effects.

EPA does not use a probabilistic approach to estimate the potential for noncarcinogenic health effects (EPA 1989b). The potential for noncarcinogenic adverse health effects is evaluated as the ratio of the daily intake for the exposure period over the RfD. This ratio is the hazard quotient (HQ). The RfD is a provisional estimate of the daily exposure to the human population, including sensitive subgroups (with uncertainty spanning perhaps an order of magnitude). The RfD is a reference dose below which appreciable risk of negative health effects during a lifetime for chronic exposure would not be expected to occur (EPA 1989b). Although EPA has derived RfDs for both chronic and subchronic exposure, only chronic exposure of over 7 years is considered in this health assessment.

The noncancer HQ assumes that there is a level of exposure (the RfD) below which it is unlikely for even sensitive populations to experience adverse noncarcinogenic health effects (EPA 1989b). The HQs for each chemical addressed in the intake and exposure pathway are summed to obtain the hazard index (HI), which allows assessment of the overall potential for noncarcinogenic health effects. An HI greater than one (HI>1) has been defined as the level of concern for potential adverse noncarcinogenic health effects (EPA 1989b).

Cancer risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of pathway-specific exposure to carcinogenic contaminants. Results of the cancer risk estimates can be compared with the acceptable risk range of 10^{-6} to 10^{-4} (or 1 in 1,000,000 to 1 in 10,000) that is the goal of EPA outlined in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

The risk to an individual resulting from exposure to chemical or radiological carcinogens is expressed as the increased probability of a cancer occurring over the course of a lifetime. The increased cancer risk is calculated by estimating the daily intake of a chemical carcinogen averaged over a lifetime multiplied by a contaminant-specific CSF. Oral and inhalation pathway-specific CSFs have been derived for certain carcinogens; some carcinogens do not have a CSF available or are presently under review by EPA. All CSFs used in the chemical risk estimate calculations were obtained from EPA's IRIS (EPA 1994a) or HEAST (EPA 1994b). RESRAD (v.5.61) was used to calculate radiological risks (Yu et al. 1993); chemical risks were calculated following EPA guidance (EPA 1989b).

The CSF converts estimated daily intakes averaged over a lifetime of exposure directly to the incremental risk of an individual developing cancer (EPA 1989b). The carcinogenic risk estimate is generally an upper-bound estimate because the CSF is typically derived as the upper 95% confidence level of the probability of response based on experimental animal data (EPA 1989b). Thus, EPA is reasonably confident that the "true risk" will not exceed the risk estimate derived through use of the CSF and is likely to be less than that predicted using CSFs (EPA 1989b).

5.2 RISK AND HAZARD INDEX ESTIMATES

Table D.11 and Table D.12 summarizes the carcinogenic risk from radionuclides in sludge and soil to the worker and trespasser. The risk to workers is estimated to be 4×10^{-7} and 2×10^{-7} for the maximum and mean sludge concentrations, respectively, which are below the EPA target range of 10^{-4} to 10^{-6}. The risk to transients from exposure to soil is estimated to be 1×10^{-7}, which is also below the EPA target range.

Carcinogenic health effects from exposure to heavy metals are summarized in Table D.12 The estimated cancer risks for both the employee exposed to maximum concentrations in sludge and trespasser receptors exposed to soil are 6×10^{-6} and 3×10^{-8}, respectively, which are within the EPA target range.

Hazard quotients from exposure to heavy metals for both employees and transients are summarized in Table D.12 The HQ for both ingestion and particulate inhalation pathways is less than the threshold of one for both receptors. Exposure to noncarcinogenic contaminants in the sludge and soil is not likely to result in adverse health effects under the employee or trespasser scenarios.

Particulate inhalation and ingestion both contribute to the risk for both chemicals and radionuclides. Risks to employees could be reduced further by procedural controls during spraying of sludge (e.g., closing the truck window, wearing a mask). The major contributing pathway to risks to trespassers on the sludge application sites is external irradiation from exposure to cobalt-60 mixed into the soil. The likelihood of a trespasser on these sites is very low, so the risks in this analysis may be overstated. Additionally, because cobalt-60 has a relatively short half-life, the potential risks would decrease over time after application ceases.

Table D.11. Summary of radiological exposure

Employee				Transient	
Dose (mrem/year)		Cancer risk		Dose (mrem/year)	Cancer risk
Mean	Maximum	Mean	Maximum		
0.0669	0.143	2E-7	4E-7	0.016	1E-7

Table D.12. Summary of chemical exposure

Employee	Transient

	HQ		Cancer risk		HQ	Cancer risk
Pathway	Mean	Maximum	Mean	Maximum		
Ingestion	0.0210	0.0320	7E-7	1E-6	0.0027	3E-8
Inhalation	0.0002	0.0002	4E-6	5E-6	0.0000	3E-9
Total	0.0212	0.0322	4E-6	6E-6	0.0027	3E-8

6. UNCERTAINTY ANALYSIS

The risks calculated in this assessment are single point estimates of risk rather than probabilistic estimates. Therefore, it is important to discuss uncertainties inherent in the risk assessment in order to place the risk estimates in proper perspective. Uncertainties can be associated with sampling data adequacy, selection of potential COCs, exposure assessment variables, and toxicity values.

The sludge is composited and analyzed at regular time intervals for the various chemical parameters. Changes in customer activities (e.g., an increase or decrease in nuclear medicine studies) can affect the character of the sludge. These changes in sludge composition could increase the uncertainty that a sample is representative of an "average" sludge. However, since the sampling is conducted frequently (daily scanning when sludge is being applied on the ORR, weekly sampling for radionuclides, monthly for heavy metals, semi-annually for organics) and the levels of detected analytes are relatively constant among samples, the uncertainty in sampling data adequacy is low.

Uncertainty is inherent in the selection of potential COCs for analysis and is associated with a number of factors. The identification of potential COCs for a human health evaluation relies on both data from the monitoring program and the application of a selection process. Considerable data on the sludge composition have been collected over the years under the city of Oak Ridge's monitoring program. The monitoring program is based on federal and state requirements for chemical components and on knowledge of its industrial customers for radiological components. The monitoring program is comprehensive, hence the uncertainty associated with the identification of potential COCs for analysis is low.

The variables used for the exposure assessment were extremely conservative and could lead to an overestimation of risk. Maximal and average values were used for the exposure point concentrations. The exposure intake assumptions were generally the EPA default values. Employee receptors were assumed to be directly underneath the spray of sludge during application, breathing at a rate indicative of heavy activity. Workers are typically in the vehicle and are taking precautions to avoid exposure. The conservative nature of the assessment results in an overestimation of potential risk.

Standard risk estimate factors were used to estimate the hazards associated with exposure to the potential COCs. There were several identifiable potential COCs for which there were no toxicity factors or slope factors, precluding their inclusion in quantitative risk estimates. Additionally, radiological contaminants with half-lives <2 months (beryllium-7 and iodine-131) were not selected for consideration in this assessment. The resulting risk estimates do not include the incremental chemical-specific risks from these potential COCs and, therefore, may underestimate risk, although the magnitude of this underestimation is not quantifiable.

Some of the procedures used and uncertainties inherent in the human health risk assessment process may tend to underestimate potential risk. However, assumptions built into this assessment tend to overestimate rather than underestimate potential risks, including conservative assumptions for exposure point concentrations and exposure scenarios.

7. SUMMARY AND CONCLUSIONS

The radiological dose (Table D.11) that an employee might receive from exposure to sludge is very low and consistent with health physics monitoring of current POTW employees involved in sludge handling and application procedures. Monitoring of employees has shown no detectable exposure to radionuclides (Mobley 1993), and there is anecdotal information that the sludge workers are in good health.

Combined chemical and radiological risks to employees exposed to sludge during the land application process are minimal and are within the EPA target range for excess lifetime cancer risk. These estimates of risk to human health should not be taken to represent absolute risk; rather, they represent the most important sources of potential relative risk from handling sludge.

Noncarcinogenic risks were estimated to be <1, for both the worker and the trespasser, indicating that no adverse effects would be expected from exposure to sludge or sludge-amended soils.

Potential carcinogenic risk to receptors infrequently contacting soils to which sludges have been applied was within the EPA target risk range. The land application areas on the ORR currently have limited access, and it is assumed that sludges will be applied to meet statutory and/or risk-based limits. Future changes in land use or access restrictions would not result in significant risks to future receptors, assuming sludge application limits were followed.

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ATTACHMENT A TO APPENDIX D - DERIVATION OF SOIL GUIDELINE CONCENTRATIONS AND SLUDGE LIMITS

There are no applicable federal sludge radioactivity standards; therefore, the state, the city of Oak Ridge, and DOE established conservative radionuclide limits for ORR sludge application (Stephenson 1994b). These limits require that the resulting average concentration of uranium and other radionuclides with longer decay periods in the receiving soil will not generally exceed two times background (Hibbitts 1989).

The concentration of radionuclides in soil at the reference sites varies widely with each sampling period, making determination of the background concentration a controversial process. Experience in other programs has shown EPA that background levels will often be much lower than site-specific risk-based levels (55 FR 30815), requiring lengthy and costly studies even where levels were significantly below health- and environment-based standards such as the risk level of 10-4 for lifetime risk of fatal cancer to the maximally exposed individual.

The city of Oak Ridge has proposed, and TDEC has approved, a risk-based model (RESRAD) for determining acceptable radionuclide concentration in sludge (Stetar 1993). The city's model was based on a basic radiation dose limit of 4 mrem/year, which is the dose limit for anthropogenic radionuclides in drinking water. It is proposed to apply this limit to sludge application activities on the ORR.

Soil guideline concentrations were derived for radionuclides assumed to potentially be in sludge that will be land applied at the ORR. The methodology involved using the RESRAD computer code (Version 5.61) and default RESRAD exposure parameters or parameters provided in "Methodology for Establishing Radionuclide Limits for Land Application of the Oak Ridge Wastewater Treatment Plant Sludge" (Stetar 1993). All parameters used in the derivation are shown in the RESRAD computer printout included with this letter. The soil guideline concentrations were estimated using a basic radiation dose limit of 4 mrem/year.

Four radionuclides (beryllium-7, iodine-131, thorium-234 and protactinium-234m) that could occur in the ORR sludge were not included in the derivation of soil guidelines because the RESRAD database does not include these radionuclides. Each of these radionuclides has a short half-life (ranging from approximately 1 minute for Pa-234m to 53 days for Be-7) and, therefore, does not build up in the environment. Lack of a soil guideline for these four radionuclides should not impact protection of health and the environment.

In keeping with the Stetar document (1993), soil guidelines were derived using a conservative farm family scenario. The farm family scenario provides a "worst-case" determination of potential exposure because the frequency and duration of exposure are assumed to be very large. In addition, the farm family scenario includes a combined child-adult receptor, which is more sensitive than an adult only, and all potential exposure pathways are included. Other receptors that may be exposed to land application sites at the ORR include transients and workers. Both of these receptors would be exposed for a much shorter frequency and duration of time. In addition, transients and workers would be exposed by fewer pathways, and workers would be likely to take precautions to limit their exposure. As a result, the use of the farm family scenario to derive soil guideline concentrations provides values that are protective of other potential receptors.

Derived soil guidelines for each radionuclide and a basic radiation dose of 4 mrem/year are shown in Table 1. The corresponding sludge limit, assuming sludge application for 10 years at a rate of 5 tons/acre/year and a mixing depth of 0.15 meters, is also provided in the table.

Table 1. Soil Guidelines calculated using RESRAD and a basic radiation dose limit of 4 mrem/year, and radionuclide limits for sludge calculated assuming sludge application for 10 years at a rate of five tons/acre/year and a mixing depth of 0.15 m.

Radionuclide	Soil Concentration Limit (pCi/g dry wt)	Sludge Limit (pCi/g dry wt)
Ac-227	0.56	12.2
Am-241	7.7	167
Co-60	0.49	10.7
Cs-137	2.0	43.6
Eu-152	1.1	24.0
Eu-155	1.0	21.8
Gd-152	19.6	427
H-3	520	11,324
K-40	5.5	120
Np-237	1.5	32.7
Pa-231	0.81	17.6
Pb-210	2.5	54.4
Pu-238	9.1	198
Pu-239	8.3	181
Ra-226	0.11	2.40
Ra-228	0.95	20.7
Tc-99	35.5	773
Th-228	0.66	14.4
Th-229	1.5	32.7
Th-230	14.8	322

U-233	30.2	658
U-234	31.0	675
U-235	7.2	157
U-238	21.1	459.5

APPENDIX E - SITE SELECTION CRITERIA FOR SLUDGE LAND APPLICATION SITES ON THE OAK RIDGE RESERVATION ACRONYMS

DOE U.S. Department of Energy

Energy Systems Lockheed Martin Energy Systems, Inc.

LAA Land Application Approvals

ORR Oak Ridge Reservation

TDEC Tennessee Department of Environment and Conservation

At the beginning of the land application program, a site evaluation committee selected potential sites for sludge application on the Oak Ridge Reservation (ORR). The committee included representatives from the U.S. Department of Energy (DOE), Lockheed Martin Energy Systems, Inc. (Energy Systems), Tennessee Department of Environment and Conservation (TDEC) Basin Office, the city of Oak Ridge, and the U.S. Department of Agriculture. Site recommendations took into account such factors as availability of land, depth of soils, proximity to surface water, depth to groundwater, amount and type of surface vegetation, threatened/endangered species, and land accessibility. Following the initial identification and approval of sites, the city of Oak Ridge performed an independent hydrogeological assessment and submitted a landfarming application for state approval on a site-by-site basis. The state responded with Land Application Approvals (LAA) (Appendix A).

Previously, site selection criteria were general and were mainly used for identifying new sludge application sites. More formal site selection criteria were recently approved and are applicable for inactive application areas that are to be reopened as well as for new application sites. These criteria are listed below and include references to the regulations that support them.

Class B Liquid Sludge Application

1. A potential site must not be located within 150 m of a public dwelling and 60 m of a road (Tennessee Guidelines for Sewage Sludge Disposal/Best Management Practice).
2. A potential site must not be located in an area designated as wetlands (40 *CFR* 503 regulations).
3. A potential site must not be located within 150 m of a U.S. or state waterway (40 *CFR* 503 regulations/Tennessee Guidelines for Sewage Sludge Disposal/Best Management Practice).
4. A potential site must not be located in an area reserved for state/federal threatened and/or endangered species. Sites adjacent to these threatened and/or endangered designated areas can be selected if a buffer zone of 30 m is established and sludge land application is shown not to adversely affect these species or designated critical habitats (NEPA, 16 *USC* 1531/Best Management Practice).
5. A potential site must not be located in the 100-year floodplain (Tennessee Fish and Game Recommendation).
6. A potential site cannot be pre-designated for any current or ongoing research projects not involving biosolids

(Energy Systems/Best Management Practice).

7. Sites designated in ORR site development planning documents for future use or other development should not be considered as potential sludge land application sites if sludge land application is shown to present potential conflicts with planning and development activities (Energy Systems/Best Management Practice).
8. A potential site must not be located in areas designated as archaeologically or historically significant. Potential sites located adjacent to these designated areas should have a buffer zone of 30 m (NEPA/16 *USC* 470/Best Management Practice).
9. A potential site must not have slopes of >8% degree grade for surface application and 12% degree grade for subsurface injection (Tennessee Guidelines for Sewage Sludge Disposal). These limits may be adjusted by TDEC at the time the LAA permit is issued.
10. A potential site may have drains and sinkholes. Liquid sludge application should be designated to preclude contamination of tributaries, ponds, lakes, and rock outcroppings that could act as a conduit for underground streams, etc. by establishing a 15-m buffer zone around the perimeters of these areas. Sludge application may not be effected within sinks or other depressions with closed contours (i.e., without surface drainage) and in areas that may provide a known, direct route for contamination of groundwater sources (40 *CFR* 503 regulations/Tennessee Guidelines for Sewage Sludge Disposal).
11. A potential site may have karst formations present on site as long as there is ~4 ft of soil depth to a seasonal high water table (Tennessee Guidelines for Sewage Sludge Disposal).
12. A potential site must be reasonably accessible by the city's tanker truck and land application vehicles, yet restricted to public access and agricultural activities (40 *CFR* 503 regulations/Best Management Practice).
13. Potential sludge application sites should consist of soils that are reasonably permeable to allow adequate incorporation of sludge particulates. This will be determined by a TDEC representative or qualified soil scientist (Best Management Practice).
14. A potential site may have drinking water wells on site such that a 300-m buffer zone is established from active sludge land application operations (Tennessee Guidelines for Sewage Sludge Disposal).

Class B Solid Sludge Application

1. A potential site must not be located within 75 m of a public dwelling and 6 m from a road (Tennessee Guidelines for Sewage Sludge Disposal/Best Management Practice).
2. A potential site must not be located in an area designated as wetlands (40 *CFR* 503 regulations).
3. A potential site must not be located within 60 m of a U.S. or state waterway (Tennessee Guidelines for Sewage Sludge Disposal/Best Management Practice).
4. A potential site must not be located in an area reserved for state/federal threatened and/or endangered species. Sites adjacent to these threatened and/or endangered designated areas can be selected if a buffer zone of 30 m is established and sludge land application is shown not to adversely affect these species or designated critical habitats (NEPA, 16 *USC* 1531/Best Management Practice).
5. A potential site must not be located in the 100-year floodplain (Tennessee Fish and Game Recommendation).
6. A potential site cannot be pre-designated for any current or ongoing research projects (Energy Systems/DOE practice).
7. Sites designated in ORR site development planning documents for future use or other development should not be considered as potential sludge land application sites if sludge land application is shown to present potential conflicts with planning and development activities (Energy Systems/Best Management Practice).
8. A potential site must not be located in areas designated as archaeologically or historically significant. Potential sites located adjacent to these designated areas should have a buffer zone of 30 m (NEPA/16 *USC* 470/Best Management Practice).
9. A potential site must not have slopes of >8% degree grade (Tennessee Guidelines for Sewage Sludge Disposal). These limits may be adjusted by TDEC at the time the LAA permit is issued.
10. A potential site may have drains and sinkholes. Solid sludge application should be designed to preclude contamination of tributaries, ponds, lakes, etc. by establishing a 10-m buffer zone around the perimeters of these areas. Sludge application may not be effected within sinks or other depressions with closed contours (i.e., without surface drainage) and in areas that may provide a known, direct route for contamination of groundwater sources (40 *CFR* 503 regulations).
11. A potential site may have karst formations present on site as long as there is ~4 ft of soil depth to a seasonal

high water table (Tennessee Guidelines for Sewage Sludge Disposal).

12. A potential site must be reasonably accessible by the city's application vehicles, yet restricted to public access and agricultural activities (40 *CFR* 503 regulations/Best Management Practice).
13. Potential sludge sites should consist of soils that are reasonably permeable to allow adequate incorporation of sludge particulates. This will be determined by a TDEC representative or qualified soil scientist (Best Management Practice).
14. A potential site may have drinking water wells on site such that a 300-m buffer zone is established from active sludge land application operations (Tennessee Guidelines for Sewage Sludge Disposal).

Class A Solid Sludge Application

1. A potential site must not be located in an area designated as wetlands (Best Management Practice).
2. A potential site must not be located in an area reserved for state/federal threatened and/or endangered species. Sites adjacent to these threatened and/or endangered designated areas can be selected if a buffer zone of 30 m is established and sludge land application is shown not to adversely affect these species or designated critical habitats (NEPA, 16 *USC* 1531).
3. A potential site must not be located in the 100-year floodplain (Tennessee Fish and Game Recommendation).
4. A potential site must not be located in areas designated as archaeologically or historically significant (NEPA/16 *USC* 470/Best Management Practice).
5. A potential site may have tributaries, sinkholes, and underground streams. These features are not of regulatory concern because of the exceptional quality status of the sewage sludge being applied to potential sites (40 *CFR* 503 regulations).
6. A potential site must be reasonably accessible by the city's application vehicles (Best Management Practice).

Ideal Site Conditions for All Land Application Facilities

1. A closed or modified closed drainage system.
2. Slopes of <4% degree grade; steeper gradients may be acceptable on coarse-textured soils or where management practices or application methods reduce erosion hazards.
3. Medium-textured underlying materials; finer-textured or high bulk density materials are suitable for sludges if managed properly and may be suitable for waste waters if overland flow is used.
4. Soil pH values of from 6.5 to 8.2 (specific determination by a qualified soil scientist).
5. Bedrock and unconsolidated substrata, when present, free of coarse conducting layers or conduits, and at least 3 or 4 ft below the soil surface.
6. High surface soil infiltration capacity and moderate subsoil permeability.
7. A soil thickness of at least 3 ft without restrictive layers.
8. Well or moderately well-drained soil conditions to provide oxidizing conditions throughout most of the year; less well-drained soils if adequately tilled.
9. Soil having moderate to high moisture supplying capacity.
10. Medium and high levels of organic matter in the surface horizon.

APPENDIX F - UPDATE ON MERCURY CONTAMINATION IN THE SLUDGE AT THE CITY OF OAK RIDGE PUBLICLY OWNED TREATMENT WORKS

ACRONYMS

DOE U.S. Department of Energy

Energy Systems Lockheed Martin Energy Systems, Inc.

ORR Oak Ridge Reservation

POTW Publicly Owned Treatment Works

Samples taken on October 17, October 26, and November 14, 1995 from a sampling station at the Y-12 Plant indicate that mercury discharges from the Y-12 Plant sanitary sewer system exceeded the industrial pretreatment limit for discharges to the city of Oak Ridge publicly owned treatment works (POTW). A contractor had been pulling television cameras through the Y-12 Plant sewer lines as part of a cleaning contract.

On October 26, 1995, a monthly inspection of the Sludge Land Application Program identified an elevated mercury concentration in the sludge for the month of September. The city of Oak Ridge obtains a daily sample of sludge that is land applied. The daily samples are composited and submitted for laboratory analysis at the end of each month. Laboratory results are typically returned near the end of the month following the land application. The mercury concentration was reported to have been 25.34 mg/kg for September. The concentration for the previous month and the 1994 average concentration were 8.2 and 7.59 mg/kg, respectively. The city of Oak Ridge suspected that the September results were erroneous and submitted an archived sample to their laboratory for analysis.

On Tuesday, November 21, 1995 the Sludge Working Group was informed by the city of Oak Ridge POTW that the mercury concentration in POTW sludge was 86 mg/kg dry weight for sludge that was land applied in October on U.S. Department of Energy (DOE) Oak Ridge Reservation (ORR) property. This material was land applied even though it exceeded the ceiling concentration limit of 57 mg/kg. Additionally, the city of Oak Ridge indicated that the previous laboratory analysis for September was valid.

Application of sludge on the ORR was suspended. A Y-12 Plant task force began developing contingency plans for addressing the build-up of sludge at the POTW caused by the suspension of sludge land application.

Land application of POTW sludge was resumed on November 28 based on the results of additional sampling and analysis after the digesters were recirculated to mix the contents. An analysis for the composite sample of material land applied through November 21 was also available at that time and was 16.2 mg/kg, which was below the ceiling concentration limit. However due to a laboratory error, the reported results were erroneous. On December 13 the city of Oak Ridge informed Lockheed Martin Energy Systems, Inc. (Energy Systems) personnel that the correct result for the November composite sample is 324 mg/kg, which is above the ceiling concentration limit. Land application was again suspended. POTW personnel estimated that ~2 weeks of storage was available in the POTW digesters.

A meeting of the Y-12 Plant task force and other Energy Systems personnel was held on December 13 to formulate responses to the current situation. Y-12 Plant will do additional testing of the POTW sludges to confirm the POTW results and better define the situation. The task force decided to recommend that DOE provide funds to the city of Oak Ridge to hire a contractor to provide dewatering of the sludge, with subsequent disposal at the Y-12 Plant landfill, until mercury concentrations subside sufficiently to allow resumption of the land application. A special waste disposal permit was required to dispose of the dewatered sludge at the Y-12 Plant Industrial Landfill V.

Energy Systems and DOE site personnel from the Y-12 Plant task force requested a meeting with city of Oak Ridge personnel at the POTW on December 14. The recommendation to have the city procure a contractor to dewater the sludge, with reimbursement by DOE, was presented to the city of Oak Ridge personnel (including the Director of Public Works) and accepted in principle. DOE committed to deliver a letter of commitment to the Director of Public Works on December 15, and to accept the dewatered sludge for disposal (pending approval of a special waste permit) in the Y-12 Plant industrial landfill. Y-12 Plant agreed to store the dewatered sludge temporarily if needed. While agreeing to focus on the immediate problem with mercury contamination in the digesters, the city of Oak Ridge is also concerned about potential mercury contamination in other parts of the POTW and the collection system. The city of Oak Ridge City Council was notified of the dewatering action.

It is believed that the elevated mercury levels in the sludge are attributed to work recently performed on the Y-12 Plant sanitary sewer lines associated with a video survey of the system in advance of a line item sewer rehabilitation project.

The city POTW personnel have secured a private vendor to provide temporary sludge dewatering services at the POTW site. DOE has agreed to reimburse the city for reasonable costs incurred due to this activity over the course of the next 30 days (minimum).

The city of Oak Ridge (in cooperation with Y-12 Plant personnel) submitted a special waste permit application 12/21/95 to the Tennessee Department of Environment and Conservation requesting disposal of the dewatered sludge cake from the POTW in the DOE Sanitary Landfill operated by the Y-12 Plant Waste Management. Analytical data obtained on the Oak Ridge sludge confirms that the sludge is not Resource Conservation and Recovery Act hazardous and should be able to be disposed of in the DOE Landfill. Approval of the requested permit by TDEC was received December 27, 1995.

Y-12 Plant Waste Management personnel will provide transportation of dewatered sludge (via dumptruck) to the DOE Landfill beginning 12/30/95. Filtrate from the sludge dewatering process is planned to be routed back to the head end of the POTW for treatment.

Y-12 Plant Waste Management is in the final steps of readying the three basins at the S-3 Ponds Liquid Treatment Facility as a contingency to provide emergency interim containment of ~210,000 gallons of non-dewatered digested sludge. These basins are expected to be ready for possible use by 12/22/95, although there are currently no plans to utilize the basins for this purpose.

Y-12 Plant sanitary sewer monitoring data show that mercury levels in the Y-12 Plant sanitary sewage are still slightly elevated, although they do appear to be returning to normal. The video survey project is on indefinite hold.

The sludge applied in October increased the mercury cumulative loadings on the two sites (Upper Hayfield and Scarboro) that received this material, ~0.105 and 0.101 kg/ha, respectively. The cumulative loading limit for mercury is 17.0 kg/ha. Loadings, through October, are approximately 0.5 and 0.6 kg/ha. Although the addition of the October material did not cause either site to approach the cumulative loading limit, it is not known how the state and/or the U.S. Environmental Protection Agency will view the violation of the ceiling limit or if the October material represents a future remediation liability.

APPENDIX G - PART 503 PATHOGEN STANDARDS AND TREATMENT PROCESSES

Subpart D--Pathogens and Vector Attraction Reduction & #167;503.30 Scope

(a) This subpart contains the requirements for a sewage sludge to be classified either Class A or Class B with respect to pathogens.

(b) This subpart contains the site restrictions for land on which a Class B sewage sludge is applied.

(c) This subpart contains the pathogen requirements for domestic septage applied to agricultural land, forest, or a reclamation site.

(d) This subpart contains alternative vector attraction reduction requirements for sewage sludge that is applied to the land or placed on a surface disposal site.

§503.31 Special definitions

(a) **Aerobic digestion** is the biochemical decomposition of organic matter in sewage sludge into carbon dioxide and water by microorganisms in the presence of air.

(b) **Anaerobic digestion** is the biochemical decomposition of organic matter in sewage sludge into methane gas and carbon dioxide by microorganisms in the absence of air.

(c) **Density of microorganisms** is the number of microorganisms per unit mass of total solids (dry weight) in the sewage sludge.

(d) **Land with a high potential for public exposure** is land that the public uses frequently. This includes, but is not limited to, a public contact site and a reclamation site located in a populated area (e.g, a construction site located in a city).

(e) **Land with a low potential for public exposure** is land that the public uses infrequently. This includes, but is not limited to, agricultural land, forest, and a reclamation site located in an unpopulated area (e.g., a strip mine located in a rural area).

(f) **Pathogenic organisms** are disease-causing organisms. These include, but are not limited to, certain bacteria, protozoa, viruses, and viable helminth ova.

(g) **pH** means the logarithm of the reciprocal of the hydrogen ion concentration.

(h) **Specific oxygen uptake rate (SOUR)** is the mass of oxygen consumed per unit time per unit mass of total solids (dry weight basis) in the sewage sludge.

(i) **Total solids** are the materials in sewage sludge that remain as residue when the sewage sludge is dried at 103 to 105 degrees Celsius.

(j) **Unstabilized solids** are organic materials in sewage sludge that have not been treated in either an aerobic or anaerobic treatment process.

(k) **Vector attraction** is the characteristic of sewage sludge that attracts rodents, flies, mosquitos, or other organisms capable of transporting infectious agents.

(l) **Volatile solids** is the amount of the total solids in sewage sludge lost when the sewage sludge is combusted at 550 degrees Celsius in the presence of excess air.

§503.32 Pathogens

(a) Sewage sludge - Class A

(1) The requirement in §503.32(a)(2) and the requirements in either §503.32(a)(3), §503.32(a)(4), §503.32(a)(5), §503.32(a)(6), §503.32(a)(7), or §503.32(a)(8) shall be met for a sewage sludge to be classified Class A with respect to pathogens.

(2) The Class A pathogen requirements in §503.32(a)(3) through §503.32(a)(8) shall be met either prior to meeting or at the same time the vector attraction reduction requirements in §503.33, except the vector attraction reduction requirements in §503.33(b)(6) through §503.33(b)(8), are met.

(3) Class A - Alternative 1

(i) Either the density of fecal coliform in the sewage sludge shall be less than 1000 Most Probable Number per gram of total solids (dry weight basis), or the density of *Salmonella* spp. bacteria in the sewage sludge shall be less than three Most Probable Number per four grams of total solids (dry weight basis) at the time the sewage sludge is used or disposed; at the time the sewage sludge is prepared for sale or given away in a bag or other container for application to the land; or at the time the sewage sludge or material derived from sewage sludge is prepared to meet the requirements in §503.10(b), §503.10(c), §503.10(e), or §503.10(f).

(ii) The temperature of the sewage sludge that is used or disposed shall be maintained at a specific value for a period of time.

(A) When the percent solids of the sewage sludge is 7 percent or higher, the temperature of the sewage sludge shall be 50 degrees Celsius or higher; the time period shall be 20 minutes or longer; and the temperature and time period shall be determined using equation (1), except when small particles of sewage sludge are heated by either warmed gases or an immiscible liquid.

D = 131,700,000 (1)

$10^{0.1400t}$

where,

D = time in days.

t = temperature in degrees Celsius.

(B) When the percent solids of the sewage sludge is 7 percent or higher and small particles of sewage sludge are heated by either warmed gases or an immiscible liquid, the temperature of the sewage sludge shall be 50 degrees Celsius or higher; the time period shall be 15 seconds or longer; and the temperature and time period shall be determined using equation (1).

(C) When the percent solids of the sewage sludge is less than 7 percent and the time period is at least 15 seconds, but less than 30 minutes, the temperature and time period shall be determined using equation (1).

(D) When the percent solids of the sewage sludge is less than 7 percent; the temperature of the sewage sludge is 50 degrees Celsius or higher; and the time period is 30 minutes or longer, the temperature and time period shall be determined using equation (2).

D = 50,070,000 (2)

$10^{0.1400t}$

where,

D = time in days.

t = temperature in degrees Celsius.

(4) Class A - Alternative 2

(i) Either the density of fecal coliform in the sewage sludge shall be less than 1000 Most Probable Number per gram of total solids (dry weight basis), or the density of *Salmonella* spp. bacteria in the sewage sludge shall be less than three Most Probable Number per four grams of total solids (dry weight basis) at the time the sewage sludge is used or disposed; at the time the sewage sludge is prepared for sale or given away in a bag or other container for application to the land; or at the time the sewage sludge or material derived from sewage sludge is prepared to meet the requirements in §503.10(b), §503.10(c), §503.10(e), or §503.10(f).

(ii) (A) The pH of the sewage sludge that is used or disposed shall be raised to above 12 and shall remain above 12 for 72 hours.

(B) The temperature of the sewage sludge shall be above 52 degrees Celsius for 12 hours or longer during the period that the pH of the sewage sludge is above 12.

(C) At the end of the 72-hour period during which the pH of the sewage sludge is above 12, the sewage sludge shall be air dried to achieve a percent solids in the sewage sludge greater than 50 percent.

(5) Class A - Alternative 3

(i) Either the density of fecal coliform in the sewage sludge shall be less than 1000 Most Probable Number per gram of total solids (dry weight basis), or the density of *Salmonella* spp. bacteria in sewage sludge shall be less than three Most Probable Number per four grams of total solids (dry weight basis) at the time the sewage sludge is used or disposed; at the time the sewage sludge is prepared for sale or given away in a bag or other container for application to the land; or at the time the sewage sludge or material derived from sewage sludge is prepared to meet the requirements in §503.10(b), §503.10(c), §503.10(e), or §503.10(f).

(ii) (A) The sewage sludge shall be analyzed prior to pathogen treatment to determine whether the sewage sludge contains enteric viruses.

(B) When the density of enteric viruses in the sewage sludge prior to pathogen treatment is less than one Plaque-forming Unit per four grams of total solids (dry weight basis), the sewage sludge is Class A with respect to enteric viruses until the next monitoring episode for the sewage sludge.

(C) When the density of enteric viruses in the sewage sludge prior to pathogen treatment is equal to or greater than one Plaque-forming Unit per four grams of total solids (dry weight basis), the sewage sludge is Class A with respect to enteric viruses when the density of enteric viruses in the sewage sludge after pathogen treatment is less than one Plaque-forming Unit per four grams of total solids (dry weight basis) and when the values or ranges of values for the operating parameters for the pathogen treatment process that produces the sewage sludge that meets the enteric virus density requirement are documented.

(D) After the enteric virus reduction in (ii)(C) of this subsection is demonstrated for the pathogen treatment process, the sewage sludge continues to be Class A with respect to enteric viruses when the values for the pathogen treatment process operating parameters are consistent with the values or ranges of values documented in (ii)(C) of this subsection.

(iii) (A) The sewage sludge shall be analyzed prior to pathogen treatment to determine whether the sewage sludge contains viable helminth ova.

(B) When the density of viable helminth ova in the sewage sludge prior to pathogen treatment is less than one per four grams of total solids (dry weight basis), the sewage sludge is Class A with respect to viable helminth ova until the next monitoring episode for the sewage sludge.

(C) When the density of viable helminth ova in the sewage sludge prior to pathogen treatment is equal to or greater than one per four grams of total solids (dry weight basis), the sewage sludge is Class A with respect to viable helminth ova when the density of viable helminth ova in the sewage sludge after pathogen treatment is less than one per four grams of total solids (dry weight basis) and when the values or ranges of values for the operating parameters for the pathogen treatment process that produces the sewage sludge that meets the viable helminth ova density requirement are documented.

(D) After the viable helminth ova reduction in (iii)(C) of this subsection is demonstrated for the pathogen treatment process, the sewage sludge continues to be Class A with respect to viable helminth ova when the values for the pathogen treatment process operating parameters are consistent with the values or ranges of values documented in (iii)(C) of this subsection.

(6) Class A - Alternative 4

(i) Either the density of fecal coliform in the sewage sludge shall be less than 1000 Most Probable Number per gram of total solids (dry weight basis), or the density of *Salmonella* spp. bacteria in the sewage sludge shall be less than three Most Probable Number per four grams of total solids (dry weight basis) at the time the sewage sludge is used or disposed; at the time the sewage sludge is prepared for sale or given away in a bag or other container for application to the land; or at the time the sewage sludge or material derived from sewage sludge is prepared to meet the requirements in §503.10(b), §503.10(c), §503.10(e), or §503.10(f).

(ii) The density of enteric viruses in the sewage sludge shall be less than one Plaque-forming Unit per four grams of total solids (dry weight basis) at the time the sewage sludge is used or disposed; at the time the sewage sludge is prepared for sale or given away in a bag or other container for application to the land; or at the time the sewage sludge or material derived from sewage sludge is prepared to meet the requirements in §503.10(b), §503.10(c), §503.10(e), or §503.10(f), unless otherwise specified by the permitting authority.

(iii) The density of viable helminth ova in the sewage sludge shall be less than one per four grams of total solids (dry weight basis) at the time the sewage sludge is used or disposed; at the time the sewage sludge is prepared for sale or given away in a bag or other container for application to the land; or at the time the sewage sludge or material derived from sewage sludge is prepared to meet the requirements in §503.10(b), §503.10(c), §503.10(e), or §503.10(f), unless otherwise specified by the permitting authority.

(7) Class A - Alternative 5

(i) Either the density of fecal coliform in the sewage sludge shall be less than 1000 Most Probable Number per gram of total solids (dry weight basis), or the density of *Salmonella*, spp. bacteria in the sewage sludge shall be less than three Most Probable Number per four grams of total solids (dry weight basis) at the time the sewage sludge is used or disposed; at the time the sewage sludge is prepared for sale or given away in a bag or other container for application to the land; or at the time the sewage sludge or material derived from sewage sludge is prepared to meet the requirements in §503.10(b), §503.10(c), §503.10(e), or §503.10(f).

(ii) Sewage sludge that is used or disposed shall be treated in one of the Processes to Further Reduce Pathogens.

(8) Class A - Alternative 6

(i) Either the density of fecal coliform in the sewage sludge shall be less than 1000 Most Probable Number per gram of total solids (dry weight basis), or the density of *Salmonella* spp. bacteria in the sewage sludge shall be less than three Most Probable Number per four grams of total solids (dry weight basis) at the time the sewage sludge is used or disposed; at the time the sewage sludge is prepared for sale or given away in a bag or other container for application to the land; or at the time the sewage sludge or material derived from sewage sludge is prepared to meet the requirements in §503.10(b), §503.10(c), §503.10(e), or §503.10(f).

(ii) Sewage sludge that is used or disposed shall be treated in a process that is equivalent to a Process to Further Reduce Pathogens, as determined by the permitting authority.

(b) Sewage sludge - Class B

(1) (i) The requirements in either §503.32(b)(2), §503.32(b)(3), or §503.32(b)(4) shall be met for a sewage sludge to be classified Class B with respect to pathogens.

(ii) The site restrictions in §503.32(b)(5) shall be met when sewage sludge that meets the Class B pathogen requirements in §503.32(b)(2), §503.32(b)(3), or §503.32(b)(4) is applied to the land.

(2) Class B - Alternative 1

(i) Seven samples of the sewage sludge shall be collected at the time the sewage sludge is used or disposed.

(ii) The geometric mean of the density of fecal coliform in the samples collected in (2)(i) of this subsection shall be less than either 2,000,000 Most Probable Number per gram of total solids (dry weight basis) or 2,000,000 Colony Forming Units per gram of total solids (dry weight basis).

(3) Class B - Alternative 2

Sewage sludge that is used or disposed shall be treated in one of the Processes to Significantly Reduce Pathogens.

(4) Class B - Alternative 3

Sewage sludge that is used or disposed shall be treated in a process that is equivalent to a Process to Significantly Reduce Pathogens, as determined by the permitting authority.

(5) Site Restrictions

(i) Food crops with harvested parts that touch the sewage sludge/soil mixture and are totally above the land surface shall not be harvested for 14 months after application of sewage sludge.

(ii) Food crops with harvested parts below the surface of the land shall not be harvested for 20 months after application of sewage sludge when the sewage sludge remains on the land surface for 4 months or longer prior to incorporation into the soil.

(iii) Food crops with harvested parts below the surface of the land shall not be harvested for 38 months after application of sewage sludge when the sewage sludge remains on the land surface for less than 4 months prior to incorporation into the soil.

(iv) Food crops, feed crops, and fiber crops shall not be harvested for 30 days after application of sewage sludge.

(v) Animals shall not be allowed to graze on the land for 30 days after application of sewage sludge.

(vi) Turf grown on land where sewage sludge is applied shall not be harvested for 1 year after application of the sewage sludge when the harvested turf is placed on either land with a high potential for public exposure or a lawn, unless otherwise specified by the permitting authority.

(vii) Public access to land with a high potential for public exposure shall be restricted for 1 year after application of sewage sludge.

(viii) Public access to land with a low potential for public exposure shall be restricted for 30 days after application of sewage sludge.

(c) Domestic septage

(1) The site restrictions in §503.32(b)(5) shall be met when domestic septage is applied to agricultural land, forest, or a reclamation site; or

(2) The pH of domestic septage applied to agricultural land, forest, or a reclamation site shall be raised to 12 or higher by alkali addition and, without the addition of more alkali, shall remain at 12 or higher for 30 minutes and the site restrictions in §503.32(b)(5)(i) through (b)(5)(iv) shall be met.

§503.33 Vector attraction reduction

(a) (1) One of the vector attraction reduction requirements in §503.33 (b)(1) through (b)(10) shall be met when bulk sewage sludge is applied to agricultural land, forest, a public contact site, or reclamation site.

(2) Applies to home lawns and gardens.

(3) Applies to the selling or giving away of sludge.

(4) Applies to application to an active sewage sludge unit.

(5) One of the vector attraction reduction requirements in §503.33 (b)(9), (b)(10) or (b)(12) shall be met when domestic septage is applied to agricultural land, forest, or a reclamation site and one of the vector attraction reduction

requirements in §503.33 (b)(9) through (b)(12) shall be met when domestic septage is placed on an active sewage sludge unit.

(b) (1) The mass of volatile solids in the sewage sludge shall be reduced by 38 percent. (see calculation procedures in "Environmental Regulations and Technology—Control of Pathogens and Vector Attraction in Sewage Sludge," EPA-625/R-92/013, 1992, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268).

(2) When the 38 percent volatile solids reduction requirement in §503.33(b)(1) cannot be met for an anaerobically digested sludge, vector attraction reduction can be demonstrated by digesting a portion of the previously digested sewage anaerobically in the laboratory in a bench-scale unit for 40 additional days at a temperature between 30 and 37 degrees Celsius. When at the end of the 40 days, the volatile solids in the sewage sludge at the beginning of the period is reduced by less than 17 percent, vector attraction reduction is achieved.

(3) When the 38 percent volatile solids reduction requirement in §503.33(b)(1) cannot be met for an aerobically digested sewage sludge, vector attraction reduction can be demonstrated by digestion of a portion of the previously digested sludge that has a percent solids of 2 percent or less aerobically in the laboratory in a bench-scale unit for 30 additional days at 20 degrees Celsius. When at the end of the 30 days, the volatile solids in the sewage sludge at the beginning of that period is reduced by less than 15 percent, vector attraction reduction is achieved.

(4) The specific oxygen uptake rate (SOUR) for sewage sludge treated in an aerobic process shall be equal to or less than 1.5 milligrams of oxygen per hour per gram of total solids (dry weight basis) at a temperature of 20 degrees Celsius.

(5) Sewage sludge shall be treated in an aerobic process for 14 days or longer. During that time, the temperature of the sewage sludge shall be higher than 40 degrees Celsius and the average temperature of the sewage sludge shall be higher than 45 degrees Celsius.

(6) The pH of sewage sludge shall be raised to 12 or higher by alkali addition and, without the addition of more alkali, shall remain at 12 or higher for 2 hours and then at 11.5 or higher for an additional 22 hours.

(7) The percent solids of sewage sludge that does not contain unstabilized solids generated in a primary wastewater treatment process shall be equal to or greater than 75 percent based on the moisture content and total solids prior to mixing with other materials.

(8) The percent solids of sewage sludge that contains unstabilized solids generated in a primary wastewater treatment process shall be equal to or greater than 90 percent based on the moisture content and total solids prior to mixing with other materials.

(9) Applies to sewage sludge that shall be injected below the surface of the land.

(10) (i) Sewage sludge applied to the land surface or placed on a surface disposal site shall be incorporated into the soil within 6 hours after application to or placement on the land.

(ii) When sewage sludge that is incorporated into the soil is Class A with respect to pathogens, the sewage sludge shall be applied or placed on the land within 8 hours after being discharged from the pathogen treatment process.

(11) Applies to sewage sludge to be placed on an active sewage sludge unit.

(12) The pH of domestic septage shall be raised to 12 or higher by alkali addition and, without the addition of more alkali, shall remain at 12 or higher for 30 minutes.

PATHOGEN TREATMENT PROCESSES

A. PROCESSES TO SIGNIFICANTLY REDUCE PATHOGENS (PSRP)

1. Aerobic digestion

Sewage sludge is agitated with air or oxygen to maintain aerobic conditions for a specific mean cell residence time at a specific temperature. Values for the mean cell residence time and temperature shall be between 40 days at 20 degrees Celsius and 60 days at 15 degrees Celsius.

2. Air drying

Sewage sludge is dried on sand beds or on paved or unpaved basins. The sewage sludge dries for a minimum of 3 months. During 2 of the 3 months, the ambient average daily temperature is above 0 degrees Celsius.

3. Anaerobic digestion

Sewage sludge is treated in the absence of air for a specific mean cell residence time at a specific temperature. Values for the mean cell residence time and temperature shall be between 15 days at 35 to 55 degrees Celsius and 60 days at 20 degrees Celsius.

4. Composting

Using either the within-vessel, static aerated pile, or windrow composting methods, the temperature of the sewage sludge is raised to 40 degrees Celsius or higher and remains at 40 degrees Celsius or higher for 5 days. For 4 hours during the 5 days, the temperature in the compost pile exceeds 55 degrees Celsius.

5. Lime stabilization

Sufficient lime is added to the sewage sludge to raise the pH of the sewage sludge to 12 after 2 hours of contact.

B. PROCESSES TO FURTHER REDUCE PATHOGENS (PFRP)

1. Composting

Using either the within-vessel composting method or the static aerated pile composting method, the temperature of the sewage sludge is maintained at 55 degrees Celsius or higher for 3 days.

Using the windrow composting method, the temperature of the sewage sludge is maintained at 55 degrees or higher for 15 days or longer. During the period when the compost is maintained at 55 degrees or higher, there shall be a minimum of five turnings of the windrow.

2. Heat drying

Sewage sludge is dried by direct or indirect contact with hot gases to reduce the moisture content of the sewage sludge to 10 percent or lower. Either the temperature of the sewage sludge particles exceeds 80 degrees Celsius or the wet bulb temperature of the gas in contact with the sewage sludge as the sewage sludge leaves the dryer exceeds 80 degrees Celsius.

3. Heat treatment

Liquid sewage sludge is heated to a temperature of 180 degrees Celsius or higher for 30 minutes.

4. Thermophilic aerobic digestion

Liquid sewage sludge is agitated with air or oxygen to maintain aerobic conditions and the mean cell residence time of the sewage sludge is 10 days at 55 to 60 degrees Celsius.

5. Beta ray irradiation

Sewage sludge is irradiated with beta rays from an accelerator at dosages of at least 1.0 megarad at room temperature (ca. 20 degrees Celsius).

6. Gamma ray irradiation

Sewage sludge is irradiated with gamma rays from certain isotopes, such as Cobalt-60 and Cesium-137, at room temperature (ca. 20 degrees Celsius).

7. Pasteurization

The temperature of the sewage sludge is maintained at 70 degrees Celsius or higher for 30 minutes or longer.