# DISPOSAL OF SHORT-LIVED RADIONUCLIDE WASTES IN SANITARY LANDFILLS

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## ABSTRACT

The Texas Low-Level Radioactive Waste Disposal Authority has sponsored an analysis of the use of permitted sanitary landfills for the disposal of wastes containing only low concentrations of radionuclides with half-lives less than 300 days. Multipathway risk assessments have been performed giving limits on concentrations and total curies annually disposed for 55 short-lived radionuclides. Disposal of such wastes in a sanitary landfill could affect more than one-third of the LLW from hospitals, universities, and industries. In the analysis, annual doses to the most exposed individual and health impacts to a collective population are calculated for two reference situations including a large metropolitan area with many waste generators and a small suburban area with only a few generators. Conservative assumptions are used in formulating the scenarios for analysis.

## INTRODUCTION

The Texas Low-Level Radioactive Waste Disposal Authority (Authority) has investigated the use of Texas Department of Health permitted type I sanitary landfills for the disposal of wastes containing only low concentrations of short-lived radionuclides (1,2).

Federal agencies have recently recognized the need for de minimis and below regulatory concern levels for radioactive waste disposal. The Nuclear Regulatory Commission (NRC) and the Texas Department of Health have developed a de minimis biomedical waste disposal rule for H-3 and C-14 which places limits on concentrations that can be disposed of without regard to radioactivity (3,4). Recently, the Texas Department of Health added I-125 to this rule. The recent 1985 amendments to the Nuclear Waste Policy Act have directed the NRC to develop by mid-1986 standards and procedures for considering and acting upon petitions for below regulatory concern disposal (5). The Environmental Protection Agency is also developing a generally applicable below regulatory concern regulation for sanitary landfill disposal as part of their low-level radioactive waste disposal rulemaking (6).

The Atomic Industrial Forum has sponsored studies relating to de minimis disposal of nuclear power reactor waste streams (7,8). The first report (7), published in 1978, used a dose guideline of 1 mrem/yr and mainly was based upon residences placed directly over undiluted wastes, a scenario that is not applicable to the present work. Thus, the resulting limiting nuclide concentrations are lower than those from the present study.

Another Atomic Industrial Forum study (8), also used a 1 mrem/yr dose guideline and focused on long-lived nuclides from reactor wastes. Limiting concentrations presented in Ref. 8 are similar to the limiting concentrations for short-lived nuclides obtained in this study.

## WASTE SOURCE TERM FOR SHORT-LIVED RADIONUCLIDES IN TEXAS

Radioactive isotope users in Texas currently produce about 28,000 $ft^3$ of low-level radioactive wastes annually, almost entirely by medical institutions, universities, and industry. This volume will increase to about 120,000 $ft^3$ annually as four nuclear power reactors become operational. As shown in Table I, there are 55 nuclides of interest with half-lives between 1.6 hours and 300 days. As least 20 of these have been used by Texas institutions and industries. Also shown in the Table are concentration and annual generator curie limits obtained by the analysis.

TABLE I

Nuclides, Limiting Concentrations and Activity Limits for Waste Generators

| Nuclide | Half Life | Concentration Limit ($Ci/m^3$) | Annual Generator Inventory Limit (Ci/yr) |
|---|---|---|---|
| F-18 | 1.658 h | 3.E-1 | 8.E+0 |
| Si-31 | 1.83 h | 1.E+2 | 3.E+3 |
| Na-24 | 1.83 h | 9.E-4 | 2.E-2 |
| P-32 | 2.18 h | 2.E+0 | 5.E+1 |
| P-33 | 2.62 h | 1.E+1 | 3.E+2 |
| S-35 | 6.02 h | 9.E+0 | 2.E+2 |
| Ar-41 | 12.36 h | 3.E-1 | 8.E+0 |
| K-42 | 13.1 h | 2.E-2 | 5.E-1 |
| Ca-45 | 15.02 h | 4.E+0 | 1.E+2 |
| Ca-47 | 20.8 h | 2.E-2 | 5.E-1 |
| Sc-46 | 35.4 h | 2.E-3 | 5.E-2 |
| Cr-51 | 40.23 h | 6.E-1 | 2.E+1 |
| Fe-59 | 64 h | 5.E-3 | 1.E-1 |
| Co-57 | 64.1 h | 6.E-2 | 2.E+0 |
| Co-58 | 64.7 h | 1.E-2 | 3.E-1 |
| Zn-65 | 66.02 h | 7.E-3 | 2.E-1 |
| Ga-67 | 67.9 h | 3.E-1 | 8.E+0 |

TABLE I
(Continued)

| Nuclide | Half Life | Concentration Limit (Ci/m$^3$) | Annual Generator Inventory Limit (Ci/yr) |
|---|---|---|---|
| Se-75 | 3.0 d | 5.E-2 | 1.E+0 |
| Br-82 | 3.26 d | 2.E-3 | 5.E-2 |
| Rb-86 | 3.61 d | 4.E-2 | 1.E+0 |
| Sr-85 | 4.54 d | 2.E-2 | 5.E-1 |
| Sr-89 | 5.29 d | 8.E+0 | 2.E+2 |
| Y-90 | 8.041 d | 4.E+0 | 1.E+2 |
| Y-91 | 10.99 d | 4.E-1 | 1.E+1 |
| Zr-95 | 12.79 d | 8.E-3 | 2.E-1 |
| Nb-95 | 13.58 d | 8.E-3 | 2.E-1 |
| Mo-99 | 14.28 d | 5.E-2 | 1.E+0 |
| Tc-99m | 18.65 d | 1.E+0 | 3.E+1 |
| Rh-106 | 25.3 d | 1.E+0 | 3.E+1 |
| Ag-110m | 27.71 d | 2.E-3 | 5.E-2 |
| Cd-115 | 31 d | 2.E-1 | 5.E+0 |
| I-133 | 60.2 d | 2.E-2 | 5.E-1 |
| Xe-133 | 65.2 d | 1.E+0 | 3.E+1 |
| Xe-127 | 65.5 d | 8.E-2 | 2.E+0 |
| Ba-140 | 71.3 d | 2.E-3 | 5.E-2 |
| La-140 | 74.2 d | 2.E-3 | 5.E-2 |
| Ce-141 | 83.8 d | 4.E-1 | 1.E+1 |
| Ce-144 | 87.2 d | 1.E-3 | 3.E-2 |
| Pr-143 | 115 d | 6.E+0 | 2.E+2 |
| Nd-147 | 120 d | 7.E-2 | 2.E+0 |
| Yb-169 | 163 d | 6.E-2 | 2.E+0 |
| Ir-192 | 243.7 d | 1.E-2 | 3.E-1 |
| Au-198 | 245 d | 3.E-2 | 8.E-1 |
| Hg-197 | 252 d | 8.E-1 | 2.E+1 |
| Tl-201 | 271 d | 4.E-1 | 1.E+1 |
| Hg-203 | 284.4 d | 1.E-1 | 3.E+0 |

The physical form of low-level waste varies from liquids, paper, and fabrics to biological tissues and activated metals. In general, they can be grouped into the following categories (9,10):

1. Dry Solids - protective clothing, gloves, small tools, plastics, rags, paper, and packaging materials are typical waste from all institutional sources.
2. Liquid Scintillation Wastes - scintillation cocktail, consisting of an organic fluid and contained in a plastic or glass vial. Liquid scintillation waste consists of both the liquid and the vial, although sometimes the two are disposed of separately.
3. Organic Liquids - organic laboratory solvents such as alcohols, aldehydes, ketones, and organic acids (excluding scintillation fluids).
4. Aqueous Liquids - most liquids associated with the medical use of radionuclides are aqueous. The washings from contaminated laboratory ware in research facilities are included in this waste type.
5. Biological Wastes - these wastes include animal carcasses used in biological research, animal bedding and excreta, and labeled cultural media.
6. Gaseous Wastes - hospitals often use gaseous xenon-133 or xenon-127 for ventilation studies of patients' lung capacities. Most of these gases can be trapped in activated charcoal filters which then must be treated as low-level waste.

Liquids are usually either placed in adsorbent materials or directly solidified in cement or other approved solidification agents. The waste forms generally associated with the main short-lived nuclides are shown in Table II. For conservatism in the present calculations, no credit is given explicitly for waste form. The contaminated materials are assumed to begin leaching from the sanitary landfill as soon as they are emplaced, and to have a leach constant of unity. Furthermore, since complexing and chelating agents may come in contact with the radioactive contamination in the sanitary landfill, none of the nuclides are assumed to be retarded in their migration through either the three-foot compacted clay liner or the natural soils beneath the sanitary landfill.

TABLE II

Radionuclides Commonly Found in Low-Level Waste

| Radio-nuclide | Dry Solids | Liquids | Liquid Scintil-lation Vials | Biological | Sealed Sources |
|---|---|---|---|---|---|
| S-35 | X | X | X | X | --- |
| Ca-45 | X | X | --- | X | --- |
| Cr-51 | X | X | --- | X | --- |
| Co-57 | X | X | --- | X | X |
| Co-58 | X | X | --- | X | --- |
| Fe-59 | X | X | --- | X | --- |
| Ga-67 | X | X | --- | --- | --- |
| Se-75 | X | X | --- | --- | --- |
| Rb-85 | X | X | X | X | --- |
| Sr-85 | X | X | --- | --- | --- |
| Tc-99m | X | X | --- | --- | --- |
| Mo-99 | X | --- | --- | --- | --- |
| In-111 | X | X | --- | --- | --- |
| Sn-113 | X | X | --- | --- | --- |
| I-123 | X | X | --- | --- | --- |
| I-125 | X | X | X | X | X |
| I-131 | X | X | X | X | --- |
| Xe-133 | --- | --- | --- | --- | --- |
| Yb-169 | X | X | --- | X | --- |
| Ir-192 | X | --- | --- | --- | X |
| Tl-201 | X | X | --- | --- | --- |
| Hg-203 | X | X | --- | --- | --- |

Any packaging is assumed to have been destroyed in emplacement with release of the contaminated materials as fine dust. The dust loading in the air is assumed to be similar to that from mechanical disturbance of natural soils, and no consideration is given for dust control measures or face masks.

Nuclide dose conversion factors are used to relate nuclide ingestion rates, inhalation rates, and ground concentrations to annual whole body dose equivalents (doses). Consistent with the use of the EPA methodology, the PRESTO-CPG (11) code was used to obtain the dose conversion factors. PRESTO-CPG was developed by EPA for use in their low-level waste disposal rulemaking. It contains the subroutine DARTAB for calculating whole body dose conversion factors using the EPA health effects data file RADRISK.

## REFERENCE SANITARY LANDFILLS

Sanitary landfills must comply with state municipal solid waste management regulations (12) for Type I sanitary landfills if they serve more than 5000 persons. For a Type I facility, all solid waste is compacted and covered at least daily with a minimum of six inches of soil, and ultimately covered with at least two feet of soil. No disposal operations are to occur within 50 feet of the site boundary or 25 feet of any pipeline, underground utility, or electrical transmission line easement. Operations are to be conducted to minimize surface water entering open trenches or contaminated surface water leaving the site boundary.

The facility must be designed to be protected from a 100-year flood and must also be designed not to contaminate the groundwater. A liner or natural foundation soil must provide the equivalent protection of three feet of soil with a permeability of not more than $1 \times 10^{-7}$ cm/sec. Waste cannot be deposited within 500 feet of a drinking water supply well, intake of a water treatment plant, or raw water intake which furnishes water for human consumption. Additional requirements include restricted access, no scavenging and other actions that ensure containment of contaminants during operations and after closure.

Two reference sanitary landfill sites are selected for the analysis. These two areas represent general extremes of disposal conditions. One, the Houston metropolitan area, is representative of a large metropolitan area with many generators of low-level radioactive waste. The second, College Station, is characteristic of a small suburban area with a single relatively large low-level radioactive waste generator.

The landfills were examined to determine disposal conditions to be used in the performance assessment. The characteristics considered for these two areas include the following:

1. Proximity of disposal facilities to radioactive waste generators.

2. Sanitary landfill characteristics.

3. Total radioactive waste and total municipal waste generation in the vicinity.

4. Hydrogeologic conditions.

   - Distance from bottom of disposal unit to water table or aquifer.
   - Permeability of native material under disposal units.

5. Annual precipitation.

6. Evapotranspiration potential.

The Houston area generates about 8200 tons of waste per day, or about six million cubic meters annually. The reference sanitary landfill in the Houston area is conservatively assumed to receive 15 percent of this waste, or $9 \times 10^5$ cubic meters per year. The volume of radioactive waste containing radionuclides with half-lives shorter than 300 days that was shipped by Houston-area generators to disposal facilities in a year is typically about 5600 cubic feet (158 cubic meters), based on State of Texas surveys (2,13).

Exposures to the transportation workers (assumed to be truck drivers) are controlled by the amount of time that any such worker might spend in close proximity to the waste (time spent collecting and transporting the waste to the disposal facility) and by the concentrations of the radionuclides in the waste. The fraction of time a transportation worker could spend in close proximity to the waste can be represented as the ratio of the volume of short-lived radionuclide waste picked up from generator sites to the total volume a worker could deliver to the disposal facility in a year. For this evaluation, it was assumed that a single transportation worker would collect ten percent of the short-lived radionuclide waste for the entire Houston area and deliver it to the sanitary landfill. For conservatism it was also assumed that all the short-lived radionuclide waste would be delivered to the same sanitary landfill. The transportation worker was estimated to make two deliveries per day to the disposal facility, and spend approximately 5.5 hours per day in close proximity to the short-lived radionuclide waste (14). Thus, over the entire year, a worker would collect and deliver 520 loads to the disposal facility, with 0.2 percent of the waste containing short-lived nuclides.

In the College Station area, the total volume of short-lived radionuclide waste that is shipped in a year is about 750 cubic feet (22 cubic meters) (2,13). The population served by the single sanitary landfill in the College Station area is about 37,000 persons. Based on the "population equivalent" generation rate of five pounds per person per day (12), the total municipal waste generated and disposed of in a year is about 103,000 cubic yards (79,000 cubic meters). Allowing for a reference distance to the disposal facility of nine miles, and an average speed of 20 mph, including time spent dumping the load, one transportation worker is capable of collecting and delivering 930 loads to the disposal facility in a year. Assuming that a single transportation worker collects and delivers all short-lived radionuclide waste generated in the vicinity, about 0.12 percent of the waste he handles is short-lived nuclides waste.

## PATHWAY DOSE ASSESSMENTS

The methodology used by EPA for estimating risks from the sanitary landfill disposal of below regulatory concern waste is used for the multipathway risk analysis of short-lived radionuclide waste generated in Texas and disposed in a sanitary landfill. In addition, the transportation accident scenarios were included in the analysis.

The methodology used by EPA to compute annual doses to the critical population group is contained in the PATHRAE computer model (15), except external gamma doses to waste transportation workers (16), and transportation accidents (17), which are calculated separately. These models are capable of analyzing the pathways listed in Fig. 1.

When considering the scenarios for short-lived nuclide wastes, only the following pathways were limiting:

1. External gamma from transportation of the waste.

2. Smoke inhalation from a truck accident and fire.

3. Groundwater migration to a nearby well.

Since approximately 80 percent of the limiting concentrations are from gamma exposures for a transportation worker in the metropolitan area, the equation for this pathway is shown as an example. It is:

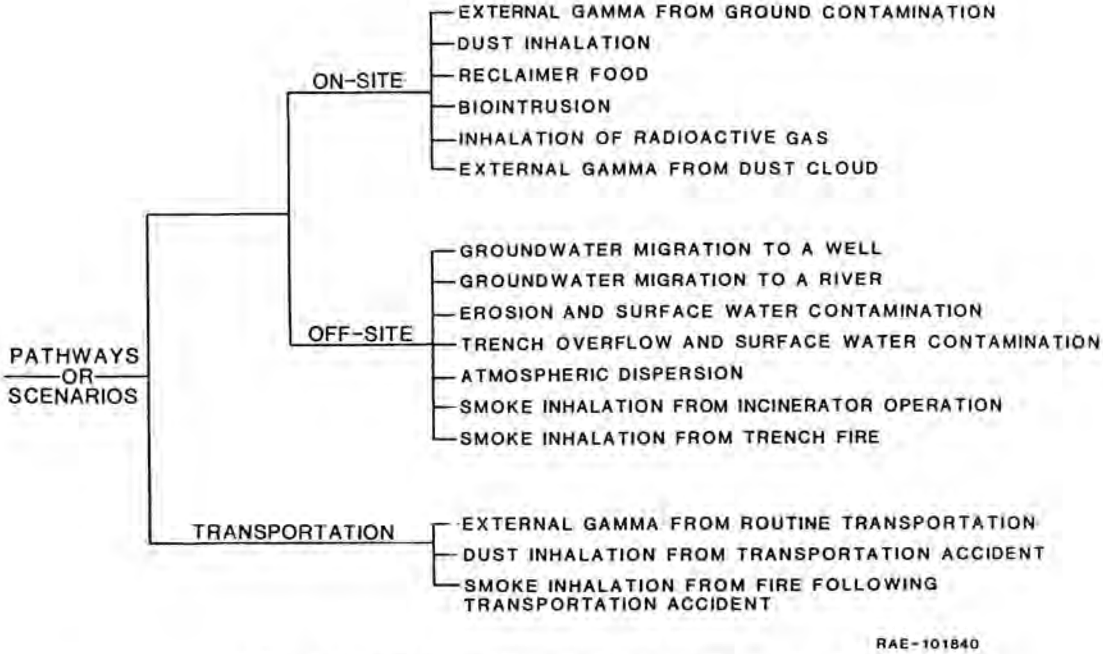


Fig. 1. Total pathways included in the methodology.

$$D_c = C_w \cdot \left(\frac{d_s}{d_w}\right) \cdot f_v \cdot PK \cdot CF \cdot DF \cdot EDF \cdot \frac{DF_g}{\mu(E_g)} \cdot \exp\left[\frac{d_{Fe}}{d_s} \cdot \mu(Eg) \cdot x\right],$$

where

$D_c$ = annual dose criterion (1 mrem/yr)

$C_w$ = nuclide concentration in the waste ($Ci/m^3$)

$d_s$ = soil density (1.6 $gcm^3$)

$d_w$ = waste density (0.3 $g/cm^3$)

$f_v$ = volume fraction of SLN waste to total waste transported annually (M=0.0020, S=0.0013)

PK = package factor (maximum value assumed, 1.33)

CF = geometry correction factor (0.187)

Df = distance correction factor (maximum value used, 1.0)

$DF_g$ = dose conversion factor for external gamma

$\mu(E_g)$ = linear attenuation coefficient for gamma rays of energy $E_g$ in soil ($m^{-1}$)

EDF = effective fraction of a year that the truck is filled with waste (0.0831)

$d_{Fe}$ = density of iron (7.86 $g/cm^3$)

x = shielding thickness provided by truck body and cab (0.03 m)

Allowance is also made for 12 hours of radioactive decay between the time a waste measurement is made and the average time of exposure to the transportation worker. Other pathway equations are given in Refs. 1 and 2.

The concentration and annual generator limits are given in Table I. Potential external gamma doses to the transportation worker constitute the limiting pathway, except for P-32, P-33, S-35, Ca-45, Sr-89, Y-90, I-125, and Pr-143 which are not strong gamma emitters. Smoke inhalation from the truck accident is the limiting pathway for these nuclides. The groundwater pathway is limiting for Co-57 and Ce-144. Smoke inhalation from operation of an incinerator or from a landfill fire are not limiting pathways for any of the short-lived nuclides that are evaluated.

It is concluded from this study that short-lived nuclide waste can be safely disposed in a sanitary landfill. A significant savings in transportation and disposal costs will result from sanitary landfill disposal of wastes containing only radionuclides with half-lives less than 300 days.

## PUBLIC AND REGULATORY RESPONSE

In July 1986, the Authority requested the Texas Department of Health to institute a rule change to allow the municipal landfill disposal of short-lived radioactive wastes below the concentration and annual curie limits established by the technical analysis. The rule change would also included an exemption from the U.S. Department of Transportation radioactive material labeling requirements. The rule change would not exempt the wastes from other hazardous waste regulations.

Staff of the Bureau of Radiation Control of the Texas Department of Health reviewed the request for rule change in August, 1986, and revised the proposed rule in response to regulatory concerns. The rule revisions included:

- Allowing the short-lived wastes to be disposed in a hazardous waste facility if the waste is a hazardous waste.

- Prior to disposing of these wastes, a licensee must submit procedures to the Bureau of Radiation Control for:

    (1) The physical delivery of the material to the disposal site;

    (2) Surveys to ensure the concentration and annual curie limits are not exceeded;

    (3) Maintaining secure packaging during transportation to the site; and

    (4) Maintaining records of disposals of these wastes.

The rule was formally proposed on January 2, 1987, and a public hearing was also held in January. Comments received on the rule were generally supportive, with some minor concerns expressed. The close of the formal comment period was February 10, 1987. The rule is expected to go into effect in April, 1987, saving Texas waste generators about $600,000 in 1987 low-level waste disposal costs.

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