APPENDIX M
RELEASE TO VADOSE ZONE

This appendix describes methods used to estimate release rates to the vadose zone, summarizes values of parameters used in the release models, summarizes results of application of the models, and presents a sensitivity analysis for particular cases.

M.1 INTRODUCTION

The assessment of human health impacts is an important element of analysis for this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)*. Activities associated with alternatives under consideration for tank closure and waste management include the placement of waste containing radiological and chemical constituents in the vadose zone at the Hanford Site (Hanford). In addition, past practices resulting in spills, leaks, planned discharge, and the disposal of waste also placed such materials in the vadose zone. Major steps in assessing human health impacts are estimation of release rates to the vadose zone, rate of transport through the vadose zone, rate of transport through the unconfined aquifer, and magnitude of health impact at the point of exposure. This appendix describes methods used to estimate release rates to the vadose zone, summarizes values of parameters used in the release models, summarizes results of application of the models, and presents a sensitivity analysis for particular cases. Although best available data and models are used to develop the analysis described in this appendix, uncertainty in results remains. The uncertainty derives from variability in natural and engineered materials, such as soil and grout and lack of knowledge, such as applicability of specific models to site-specific locations or type of climate experienced in the future. The release models described in this appendix are applicable for sources defined within the *TC & WM EIS* alternatives and for sources associated with the cumulative analysis. Further detail on sources associated with cumulative analysis is presented in Appendix S.

M.2 DESCRIPTION OF RELEASE MODELS

A variety of sources with related release mechanisms needed to be analyzed for this *TC & WM EIS*. To provide a consistent approach and to ensure quality results, the stepwise procedure summarized in Table M–1 was applied for release model development. Releases to the vadose zone may be characterized according to the physical phase of the source and by the rate controlling mechanism of the release. For this *TC & WM EIS*, releases to the vadose zone are characterized as occurring from the liquid or solid phase sources. For solid sources, release may be controlled by liquid-solid phase partitioning, solubility, or diffusion mechanisms. For each release model, the variation in time of infiltration rate is represented as a series of pulses. The increase or decrease in the infiltration rate reflects the change in conditions, including the removal or recovery of vegetation and the placement and weathering of an engineered barrier. The form of the time dependence of the infiltration rate is presented in Figure M–1. The balance of this section describes release models for this set of sources and mechanisms.

Table M–1. Steps in Release Model Development

Step Number	Content
1	Identify sources and characterize physical processes
2	Develop conceptual model of the release process
3	Develop mathematical description of the release
4	Develop algorithm for solution of mathematical model
5	Develop computer code implementing equations and solution algorithm
6	Verify computer code, including documentation of concepts, equations, and algorithms and execution of test cases
7	Apply release model

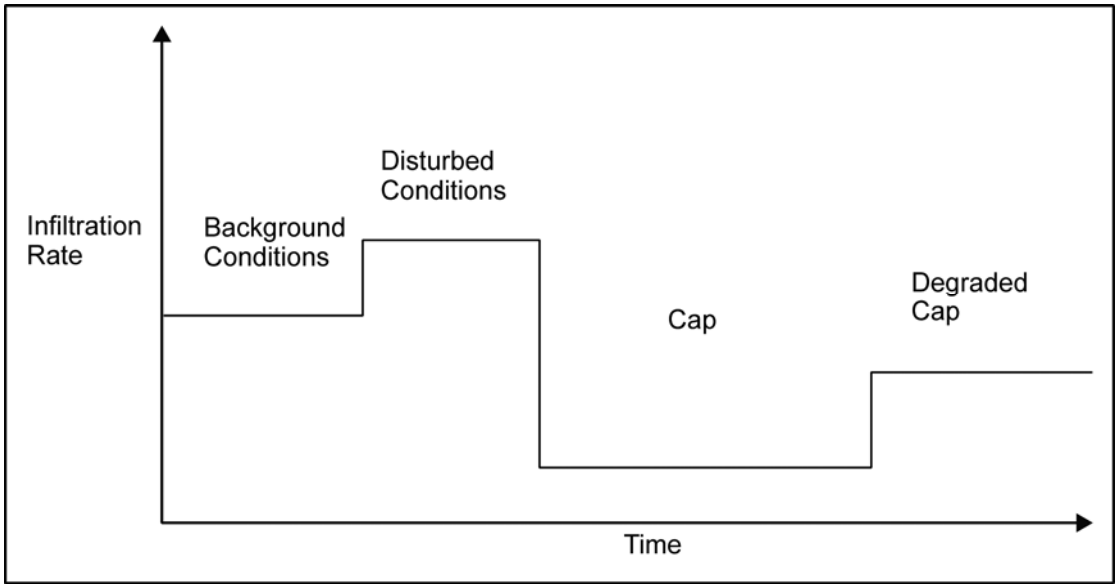


Figure M–1. Time Dependence of Infiltration Rate

M.2.1 Liquid Sources

The set of types of sources for liquid releases include planned discharges to near-surface facilities, unplanned releases to near-surface soil, past leaks from tanks, and retrieval leaks from tanks. For a given location, the release model is defined by the specification of the elevation, the area and aqueous volume of the source, the duration of the release, and inventories of constituents released during the specified time interval.

M.2.2 Solid Sources

Releases from solid sources are categorized according to the mechanism of release. Release mechanisms include partitioning from the solid to liquid phase with convective flow through the waste form, waste form dissolution with convective flow through or around the waste form, fractional release, partitioning from the solid to liquid phase with diffusive transport in the waste form, and constituent solubility limited release. The balance of this section describes details of release models for each mechanism.

M.2.2.1 Partitioning-Limited, Convective Flow Release Model

In the partitioning-limited, convective flow release model, the waste form of a given cross-sectional area with a constant thickness perpendicular to an infiltrating flow of water is located in the vadose zone. A schematic representation of the concept is presented in Figure M–2.

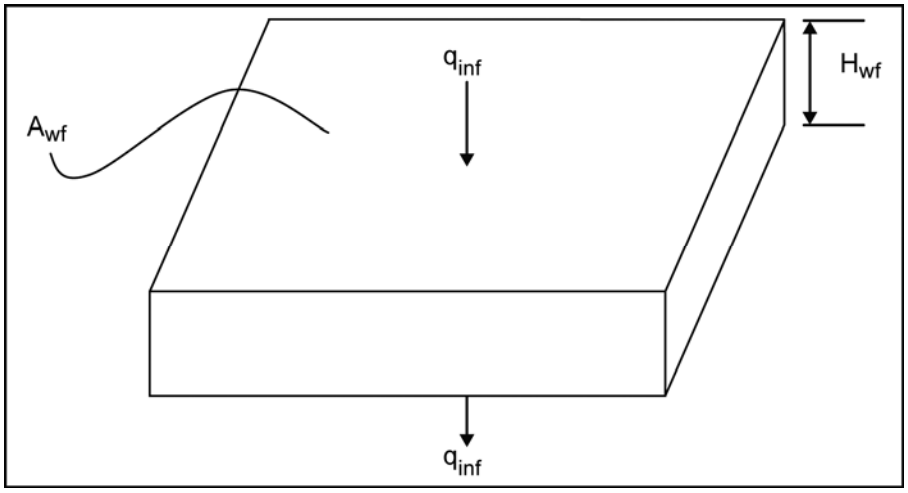


Figure M–2. Schematic of Release Concept for Partitioning-Limited, Convective Flow Release

A constituent bound to the solid is available for transfer to water moving through the waste form and the release rate is determined by the extent of partitioning between the solid and liquid phases within the waste form and the rate of movement of water through the waste form. Constituents are assumed free to move within the pore space of the waste form, producing a uniform concentration of the constituent throughout the waste form. A mass balance on a constituent within the waste form provides a relation between the liquid phase concentration and the initial mass of constituent and dimensions and properties of the waste form. The mass of the constituent within the waste form is contained within the liquid and solid phases:

$$AT = V_l C_l + V_s C_{s,v}$$

$$= \varepsilon V_t C_l + (1 - \varepsilon) V_t C_{s,v} \qquad \text{(M–1)}$$

where:

AT	=	total mass at a given time, grams
V_l	=	volume of liquid in the waste form, cubic meters
C_l	=	concentration of the constituent in the liquid phase, grams per cubic meter
V_s	=	volume of solid within the waste form, cubic meters
$C_{s,v}$	=	concentration of the constituent in the solid phase, grams per cubic meter
V_t	=	total volume of the waste form, cubic meters
ε	=	porosity of the waste form, unitless

The relationship between volumetric and mass concentration in the solid phase is:

$$C_{s,v} = \rho_s C_{s,m} \qquad \text{(M–2)}$$

where:

$C_{s,r}$	=	concentration of the constituent in the solid phase, grams per cubic meter
ρ_s	=	particle density of the solid in the waste form, grams per cubic centimeter
$C_{s,m}$	=	concentration of constituent in the solid phase, grams per gram

The relationship between concentration of the constituent in the liquid and solid phases is:

$$C_{s,m} = K_d\, C_l \tag{M–3}$$

where:

$C_{s,m}$	=	concentration of the constituent in the solid phase, grams per gram
K_d	=	distribution coefficient for the constituent in the waste form, milliliters per gram, and other variables as defined above
C_l	=	concentration of the constituent in the liquid phase, grams per cubic meter

Substitution of the supporting relations into the mass relation allows calculation of liquid phase concentration for a given inventory:

$$C_l = AT / (\varepsilon\, V_t\, R_d) \tag{M–4}$$

where:

C_l	=	concentration of the constituent in the liquid phase, grams per cubic meter
AT	=	total mass at a given time, grams
ε	=	porosity of the waste form, unitless
V_t	=	total volume of the waste form, cubic meters
R_d	=	retardation factor for the constituent in the waste form, unitless

$$R_d = 1 + [(1 - \varepsilon)/\varepsilon]\, \rho_s\, K_d \tag{M–5}$$

where:

R_d	=	retardation factor for the constituent in the waste form, unitless
ε	=	porosity of the waste form, unitless
ρ_s	=	particle density of the solid in the waste form, grams per cubic centimeter
K_d	=	distribution coefficient for the constituent in the waste form, milliliters per gram

A mass balance formed around the waste form during a time interval *j* reflects release by convection and decrease of mass within the waste form. The rate of flow of water through the waste form is equal to the rate of infiltration at the ground surface, which is represented as a series of pulses defined for a set of time intervals (see Figure M–1). The mass balance formed around the waste form is:

$$\partial\, AT/\partial t = -\, A_{wf}\, q_{\mathrm{inf,j}}\, C_l$$

$$(1/AT)\, \partial\, AT/\partial t = -\, q_{\mathrm{inf,j}} / (\varepsilon\, H_{wf}\, R_d)$$

$$= -\, f_j \tag{M–6}$$

where:

AT	=	total mass at a given time, grams
A_{wf}	=	cross-sectional area of the waste form perpendicular to flow (square meters)
$q_{\mathrm{inf,j}}$	=	rate of infiltration during time period *j* (meters per year)
C_l	=	concentration of the constituent in the liquid phase, grams per cubic meter
ε	=	porosity of the waste form, unitless
H_{wf}	=	height of the waste form parallel to flow (meters)
R_d	=	retardation factor for the constituent in the waste form, unitless

The total mass remaining in the waste form at any time in the time interval j, AT (grams), is:

$$AT = AT_{s,j} \exp\left[-f_j\,(t - t_{s,j})\right] \tag{M–7}$$

where:

$AT_{s,j}$	=	mass in the waste form at the start of time interval j, grams
t	=	time, year
$t_{s,j}$	=	time at the start of time interval j, years

The release rate of the constituent during time interval j, R_{wfj} (grams per year) is:

$$R_{wfj} = f_j\, AT_{s,j} \exp\left[-f_j\,(t - t_{s,j})\right] \tag{M–8}$$

where:

$AT_{s,j}$	=	mass in the waste form at the start of time interval j, grams
t	=	time, years
$t_{s,j}$	=	time at the start of time interval j, years

For small values of f_j or short intervals of time, the release rate can be calculated as the product of f_j and $AT_{s,j}$. The partitioning-limited, convective flow release model is applicable for contaminated soil sources and grout waste forms that have degraded over hundreds of years. Primary parameters of the model are rate of infiltration, dimensions of the waste form, and distribution coefficient of constituents.

M.2.2.2 Matrix Solubility Limited-Release Model

In the matrix solubility limited-release model, hazardous constituents are assumed to be uniformly distributed throughout a much larger mass of soluble material, such as salt cake. The matrix is porous and water flowing through the waste form dissolves the matrix and releases encapsulated constituents. The waste form is in the unsaturated zone with a downward flow as depicted in Figure M–2. The time variation of infiltration is represented as a series of step functions as shown in Figure M–1. A mass balance formed on the matrix is:

$$\partial M_{\mathrm{sc}} / \partial t = -\,A_{wf}\, q_{\mathrm{inf,j}}\, C_{s,sc} \tag{M–9}$$

where:

M_{sc}	=	mass of matrix, grams
t	=	time, years
A_{wf}	=	cross-sectional area of the waste matrix for flow, square meters
$q_{\mathrm{inf,j}}$	=	rate of infiltration, meters per year
$C_{s,sc}$	=	solubility of waste matrix, grams per cubic meter

The mass of waste matrix present at any time during a time period is:

$$M_{\mathrm{sc}} = M_{sc,j} - \left[(A_{wf}\, q_{inf,j}\, C_{s,sc})\,(t - t_{s,j})\right] \tag{M–10}$$

where:

M_{sc}	=	mass of waste matrix at time t, grams
$M_{sc,j}$	=	mass of waste matrix at start of time period j, grams
A_{wf}	=	cross-sectional area of the waste matrix for flow, square meters
$q_{inf,j}$	=	rate of infiltration, meters per year
$C_{s,sc}$	=	solubility of waste matrix, grams per cubic meter
$t_{s,j}$	=	time at start of time period j, years

During any interval, the rate of loss of waste matrix given by the second term on the right-hand side of Equation M–10 cannot exceed the amount of waste matrix present at the start of the time interval. When the waste matrix is completely removed by dissolution, the release is terminated. The release rate of hazardous constituent during time interval j equals the rate of dissolution of waste matrix multiplied by the concentration of the constituent in the matrix:

$$R_{wfj} = A_{wf}\, q_{\mathrm{inf},j}\, C_{s,sc} C_{i,m} \qquad \text{(M–11)}$$

where:

R_{wfj}	=	rate of release of constituent during time interval j, grams per year
A_{wf}	=	cross-sectional area of the waste matrix for flow, square meters
$q_{\mathrm{inf,j}}$	=	rate of infiltration, meters per year
$C_{s,sc}$	=	solubility of waste matrix, grams per cubic meter
$C_{i,m}$	=	concentration of hazardous constituent i in the waste matrix, grams per gram

The primary application of the matrix solubility limited-release model is for releases from salt cake in high-level radioactive waste (HLW) tanks under Tank Closure Alternatives 1 and 2A and from steam reforming solids under Tank Closure Alternative 3C. Primary parameters of the model are rate of infiltration, mass of the waste matrix, solubility of the waste matrix, and concentration of hazardous constituents in the waste matrix.

M.2.2.3 Fractional Release Rate Model

In chemical reactions where reactants and products are present in excess or where complex chemical and physical processes produce a constant rate of degradation of the waste form, the release rate is linearly proportional to the amount of hazardous constituent remaining at the source. The physical configuration of the waste form is the same as that represented in Figure M–2. A mass balance on the hazardous constituent at the source is:

$$\partial M / \partial t = -f_{wf} M \qquad \text{(M–12)}$$

where:

M	=	mass of hazardous constituent at the source, grams
f_{wf}	=	fractional rate of degradation of the waste form, grams per gram per year
t	=	time, years

The amount of hazardous constituent present at the source at any time is:

$$M = M_j - [f_{wf} M_j (t - t_j)] \qquad \text{(M–13)}$$

where:

M	=	mass of hazardous constituent at the source, grams
M_j	=	mass of hazardous constituent present at the source at the beginning of the time period j, grams
f_{wf}	=	fractional rate of degradation of the waste form, grams per gram per year
t	=	time, years
t_j	=	time at start of time period j, years

The release rate of the constituent from the waste form at any time is:

$$R_{wf} = f_{wf} M_j (t - t_j) \tag{M–14}$$

where:

R_{wf}	=	rate of release of the constituent from the waste form, grams per year
f_{wf}	=	fractional rate of degradation of the waste form, grams per gram per year
M_j	=	mass of hazardous constituent present at the source at the beginning of the time period j, grams
t	=	time, years
t_j	=	time at start of time period j, years

The fractional release rate model is applicable for Waste Treatment Plant (WTP) immobilized low-activity waste (ILAW) glass, bulk vitrification glass, and glass in retired melters. Primary parameters of the model are the fractional release rate constant and the initial inventory of hazardous constituents.

M.2.2.4 Diffusion Limited-Release Models

If a waste form were to have a value of hydraulic conductivity much lower than that of the surrounding material, convective flow would be diverted around the waste form. In this case, diffusive transport of the hazardous constituent within the waste form constitutes the primary mechanism for constituent release to the environment. The boundary condition specified for the concentration of the constituent outside the waste form plays a role in determining the release rate. In a conservative approach to specification of this boundary condition, the convective flow outside the waste form is assumed to maintain the concentration of the constituent at a low value at the outside boundary of the form. This maximizes the release rate of the constituent diffusing out of the waste form. In a less conservative approach to specification of this boundary condition, the rate of convective flow may be used to establish the concentration of the constituent at the boundary of the waste form. Also, the waste form may degrade over time, allowing convective flow through the form and a transition from the release controlled by diffusion to the release controlled by convection. In each case, transport by diffusion or convection occurs only in the liquid-filled pore space of the waste form, and partitioning of constituents between the solid and liquid phases is included in the release model. The geometry of the waste form is a factor in determining transport distances and the area available for release. For this *TC & WM EIS*, diffusion-controlled release models have been developed for rectangular and cylindrical geometries. For both geometries, the rate of transport by diffusion is conservatively represented by a shrinking core model to simplify the mathematical form of the model.

A source with rectangular symmetry is shown in Figure M–3.

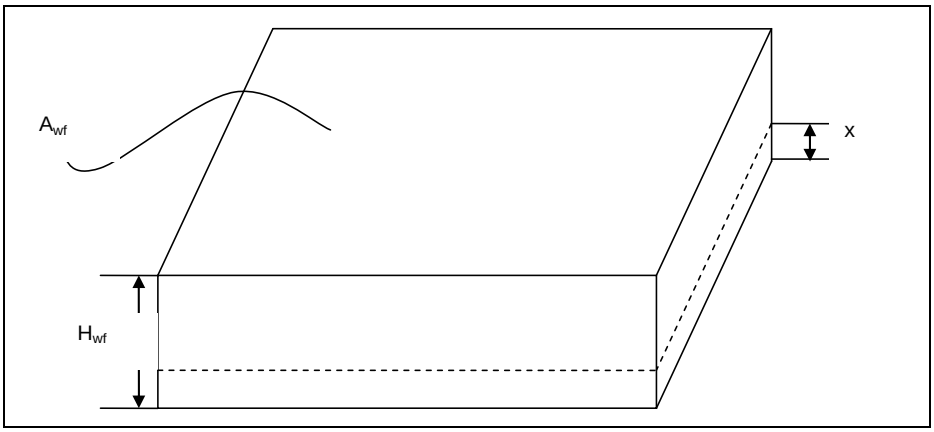


Figure M–3. Schematic of Rectangular Waste Form with Diffusion Release from Lower Surface

Resistance to mass transfer is assumed to reside in a layer, with thickness designated as x in Figure M–3, that exists between the shrinking core and the environment. The concentration of the constituent outside the waste form is assumed to be negligible. A mass balance on the diffusing constituent formed in the waste form is:

$$-\varepsilon A_{wf} T D_w (C_l / x) = A_{wf} R_d C_l \partial (H_{wf} - x) / \partial t \qquad \text{(M–15)}$$

$$R_d = 1 + [(1 - \varepsilon)/\varepsilon] \rho_s K_d \qquad \text{(M–16)}$$

where:

ε	=	porosity of the waste form, unitless
A_{wf}	=	diffusion release area of the waste form, square meters
T	=	tortuosity of the waste form, unitless
D_w	=	diffusivity of the constituent in water, square meters per year
C_l	=	concentration of the constituent in the liquid in the core portion of the waste form, grams per cubic meter
x	=	thickness of transport layer, meters
R_d	=	retardation factor for the constituent in the waste form, unitless
ρ_s	=	particle density of the solid in the waste form, grams per cubic centimeter
K_d	=	distribution coefficient for the constituent in the waste form, unitless
H_{wf}	=	thickness of waste form, meters
t	=	time, years

Assuming that the concentration of the diffusing constituent is maintained at a low level outside of the waste form, the cumulative release of the constituent from the form, $R_{wf\text{cum}}$ (grams), calculated from the mass balance is:

$$R_{wf\text{cum}} = [AT_0/(H_{wf} - x_0)] \sqrt{\{ [(2\, T D_w)/ R_d]\, t + x_0^2 \}} - [AT_0/(H_{wf} - x_0)] (x_0) \qquad \text{(M–17)}$$

where:

AT_o	=	initial inventory of the constituent, grams
H_{wf}	=	thickness of waste form, meters
x_0	=	initial thickness of the waste form layer outside the core, meters
T	=	tortuosity of the waste form, unitless
D_w	=	diffusivity of the constituent in water, square meters per year
R_d	=	retardation factor for the constituent in the waste form, unitless
t	=	time, years

This rectangular geometry model assumes that the release occurs from only the lower surface of the waste form.

If the release occurs from both the upper and lower surfaces, the waste form is represented as shown in the volume of Figure M–4. Using the same approach as for a release from a single surface, the cumulative release of the constituent from both surfaces is calculated as:

$$R_{wf\text{cum}} = [2\, AT_0/(H_{wf}/2 - x_0)]\, \sqrt{\{\, [(2\, T\, D_w)/R_d\,]\, t + x_0^2 \,\}} - [2\, AT_0/(H_{wf}/2 - x_0)]\, (x_0) \qquad \text{(M–18)}$$

where:

$R_{wf\text{cum}}$	=	cumulative release of the constituent from the waste form, grams
AT_o	=	initial inventory of the constituent, grams
H_{wf}	=	thickness of waste form, meters
x_0	=	initial thickness of the waste form layer outside the core, meters
T	=	tortuosity of the waste form, unitless
D_w	=	diffusivity of the constituent in water, square meters per year
R_d	=	retardation factor for the constituent in the waste form, unitless
t	=	time, years

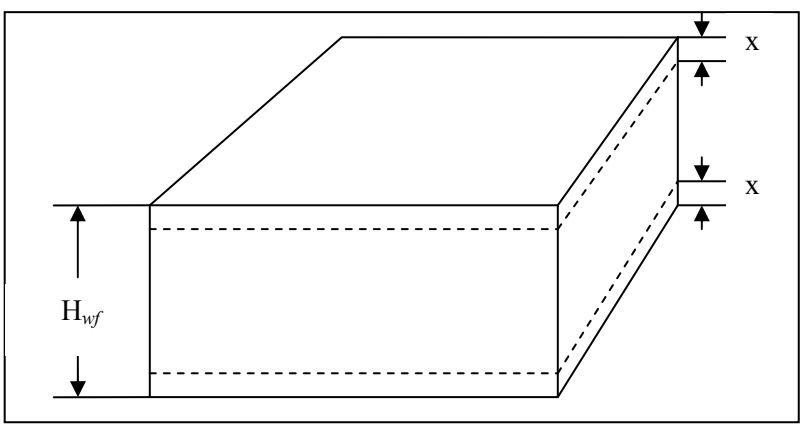


Figure M–4. Schematic of Rectangular Waste Form with Diffusion Release from Upper and Lower Surfaces

A source with cylindrical symmetry is shown in Figure M–5.

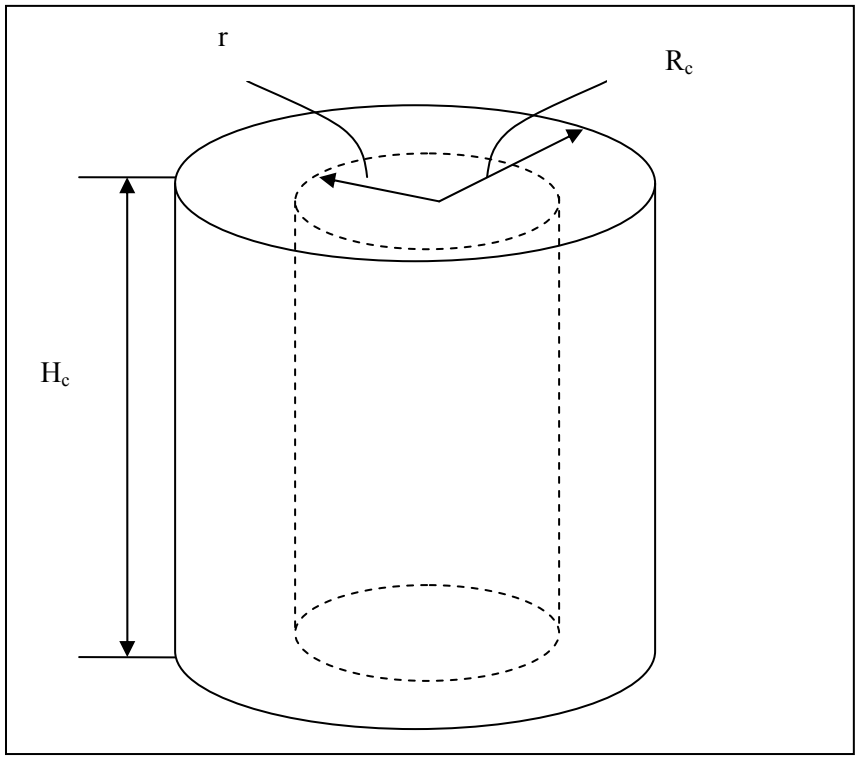


Figure M–5. Schematic of a Cylindrical Diffusion Release Model

Resistance to mass transfer is assumed to reside in an annular layer with thickness $R_c - r$ (see Figure M–5) that separates the core portion of the cylinder from the environment. Waste forms are assumed to be placed in a rectangular array, and infiltrating water flows downward through the space between waste packages. The constituent is released from the waste form by diffusion into the space between waste packages and then flows downward with the convective flow of infiltrating water. A mass balance formed on the diffusing constituent in the waste form is:

$$(\varepsilon\, \pi\, H_c)\, R_d\, C_l\, \partial\, r^2 / \partial t = -R_{wf} \qquad \text{(M–19)}$$

$$R_{wf} = (\varepsilon\, 2\, \pi\, r\, H_c)\, T\, D_w\, [(C_l - C_{vz})/(R_c - r)] \qquad \text{(M–20)}$$

$$R_d = 1 + [(1 - \varepsilon)/\varepsilon]\, \rho_s\, K_d \qquad \text{(M–21)}$$

where:

ε	=	porosity of the waste form, unitless
H_c	=	height of the cylindrical waste form, meters
R_d	=	retardation factor (see Equation M–5) for the constituent in the waste form, unitless
C_l	=	concentration of the constituent in the pore space of the waste form, grams per cubic meter
r	=	radius of the shrinking core, meters
t	=	time, years
R_{wf}	=	rate of release of the constituent from the waste form, grams per year
T	=	tortuosity of the waste form, unitless
D_w	=	diffusion coefficient of the constituent in water, square meters per year
C_{vz}	=	concentration of the constituent in the vadose zone between the waste packages, grams per cubic meter
R_c	=	radius of the cylinder, meters

ρ_s	=	particle density of the solid in the waste form, grams per cubic centimeter
K_d	=	distribution coefficient for the constituent and waste form, milliliters per gram

If the concentration of the diffusing constituent is maintained at a low level outside of the waste form ($C_{vz} = 0$), the cumulative release of the constituent from the form calculated using the mass balance is:

$$R_{wf\text{cum}} = (2\,[R_c / r_0^2]\,AT_0\,)\,\sqrt{}\,\{[(2\,T\,D_w\,)/\,R_d\,]\,t + (R_c - r_0)^2\,\} - [\,R_c - r_0\,])$$

$$-\,([\,AT_0 / r_0^2\,]\,[(2\,T\,D_w\,)/\,R_d\,]\,t\,) \qquad \text{(M–22)}$$

where:

R_{wfcum}	=	cumulative release of the constituent from the waste form, grams
R_c	=	radius of the cylinder, meters
r_0	=	initial radius of the core of the waste form, meters
AT_0	=	initial inventory of the constituent in the waste form, grams
T	=	tortuosity of the waste form, unitless
D_w	=	diffusion coefficient of the constituent in water, square meters per year
R_d	=	retardation factor (see Equation M–5) for the constituent in the waste form, unitless
t	=	time, years

If the concentration of the constituent in the vadose zone between waste forms is not maintained at a low level, the solution procedure is extended to include a mass balance formed on the constituent in the volume of soil and water in the space between waste packages. This additional mass balance is expressed as:

$$(A_f - A_{wf}\,)\,H_{wf}\,\theta_{vz}\,R_{d,vz}\,\partial\,C_{vz}\,/\,\partial t = R_{wf} - Rvz \qquad \text{(M–23)}$$

$$Rvz = A_f\,q_{\text{inf,j}}\,C_{vz} \qquad \text{(M–24)}$$

$$R_{d,vz} = 1 + [\,(1 - \varepsilon_{vz})/\,\theta_{vz}\,]\,\rho_s\,K_{d,vz} \qquad \text{(M–25)}$$

where:

A_f	=	area in horizontal plane for infiltration of water, square meters
A_{wf}	=	area in horizontal plane intersected by stacks of waste packages, square meters
H_{wf}	=	height of a stack of waste packages, meters
θ_{vz}	=	moisture content of the vadose between the waste packages, unitless
$R_{d,vz}$	=	retardation factor for the constituent in the vadose zone between waste packages, unitless
C_{vz}	=	concentration of the constituent in the water in the vadose zone between the waste packages, grams per cubic meter
t	=	time, years
R_{wf}	=	rate of release of the constituent from the waste form, grams per year
Rvz	=	rate of release of the constituent from the vadose zone between the waste packages to the vadose zone below the waste packages, grams per year
$q_{\text{inf,j}}$	=	rate of infiltration during time interval *j*, meters per year
ε_{vz}	=	porosity of the vadose zone between the waste packages, unitless
ρ_s	=	particle density of the solid in the waste form, grams per cubic centimeter
$K_{d,vz}$	=	distribution coefficient for the constituent in the vadose zone between the waste packages, milliliters per gram

Mass balances of Equations M–19 and M–23 are solved simultaneously for the concentration of the constituent in the vadose zone between waste packages (C_{vz}) and the release rates to the vadose zone below waste packages (*Rvz*).

For both the rectangular and cylindrical versions, transition to a convective flow, partition-limited release can be specified to occur after the specified design life of the waste form. Following this specified time, the release rate is calculated using Equation M–8.

Diffusion-controlled release models are applicable for grout or cement waste forms, such as grouted HLW tanks or cast stone. Primary parameters of the model are dimensions and tortuosity of the waste form, and the diffusion coefficient, distribution coefficient, and initial inventory for the constituent.

M.2.2.5 Constituent Solubility Limited-Release Model

In the constituent solubility limited-release model, a waste form of rectangular or cylindrical horizontal cross-section and uniform height is assumed to be in the vadose zone. A schematic representation is the same as that presented in Figure M–2. If the equilibrium solubility of the constituent is low, precipitation of the constituent within the waste form may occur. In addition, the constituent may partition between the liquid and solid phases of the waste form. Water moves through the waste form at the local rate of infiltration and may transport a liquid constituent in the waste form's pore space out of the form. The initial step is calculating the maximum concentration of the constituent in the pore space using the mass balance approach of Equation M–4:

$$C_l = AT_0 / (\varepsilon\, V_{wf}\, R_d) \qquad \text{(M–26)}$$

$$R_d = 1 + [(1 - \varepsilon)/\varepsilon]\, \rho_s\, K_d \qquad \text{(M–27)}$$

where:

C_l	=	maximum concentration of the constituent in the aqueous phase of the waste form, grams per cubic meter
AT_0	=	initial inventory of the constituent in the waste form, grams
ε	=	porosity of the waste form, unitless
V_{wf}	=	volume of the waste form, cubic meters
R_d	=	retardation factor for the constituent in the waste form, unitless
ρ_s	=	particle density of the waste form, grams per cubic centimeter
K_d	=	distribution coefficient for the constituent and waste form, milliliters per gram

If the concentration calculated using Equation M–26 is greater than the equilibrium solubility for the constituent, precipitation of the constituent is assumed to occur. The release rate of the constituent is estimated as:

$$R_{wf} = q_{\mathrm{inf,j}}\, C_s \qquad \text{(M–28)}$$

where:

R_{wf}	=	rate of release of the constituent from the waste form, grams per year
$q_{\mathrm{inf,j}}$	=	rate of infiltration during infiltration period *j*, meters per year
C_s	=	solubility of the constituent in groundwater, grams per cubic meter

When the mass of precipitate in the waste form is fully dissolved, the liquid phase concentration will decrease below the solubility limit. The release rate will be controlled by liquid-solid partitioning as described by Equations M–6 and M–8:

$$R_{wf} = (q_{\mathrm{inf,j}} / [\varepsilon H_{wf} R_d)]) AT_j \quad \text{(M–29)}$$

where:

$$AT_j = (\varepsilon V_{wf} R_d) C_l \quad \text{(M–30)}$$

where:

R_{wf}	=	rate of release of the constituent from the waste form, grams per year
$q_{\mathrm{inf,j}}$	=	rate of infiltration during infiltration period *j*, meters per year
ε	=	porosity of the waste form, unitless
V_{wf}	=	volume of the waste form, cubic meters
R_d	=	retardation factor for the constituent in the waste form, unitless
AT_j	=	mass of the constituent present at the termination of the solubility-controlled release, grams
C_l	=	maximum concentration of the constituent in the aqueous phase of the waste form, grams per cubic meter

The constituent limited solubility model could be applied for locations where large quantities of material with low solubility were discharged to the soil or to waste forms with local chemical environments favoring precipitation.

M.3 TECHNICAL BASIS AND VALUES OF RELEASE MODEL PARAMETERS

Factors affecting release rates of constituents to the vadose zone include environmental factors, such as rate of infiltration, and factors specific to the nature of the source and the disposal system. Values of rate of infiltration adopted for use in this *TC & WM EIS* are those recommended in the *Technical Guidance Document for Tank Closure Environmental Impact Statement, Vadose Zone and Groundwater Revised Analyses (Technical Guidance Document)* (DOE 2005). *Technical Guidance Document* values recommended for base case analysis are summarized in Table M–2. Post–design life conditions in Table M–2 correspond to the period of time labeled as "Degraded Cap" in Figure M–1.

Values of parameters related to specific actions and types of sources are summarized in the following sections for the Tank Closure, Fast Flux Test Facility (FFTF) Decommissioning, and Waste Management alternatives. Tank Closure alternatives evaluate impacts occurring in the long-term period following stabilization or closure of the HLW tanks. Under Waste Management Alternative 2, waste disposal would occur in an Integrated Disposal Facility (IDF) in the 200-East Area, (IDF-East) and facilities in 200-East and 200-West Areas under Waste Management Alternative 3.

Table M–2. Rates of Infiltration for *TC & WM EIS* Base Case Analysis

Location	Rate of Infiltration (millimeters per year)
Pre-Hanford background	
IDF	0.9
Balance of site	3.5
Disturbed conditions	
Gravel (HLW tanks)	100
Sand (cribs and trenches [ditches])	50
IDF barrier	
Design life	0.5
Post–design life	0.9
Sitewide barrier	
Design life	0.5
Post–design life	3.5

Key: HLW=high-level radioactive waste; IDF=Integrated Disposal Facility; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

M.3.1 Tank Closure Alternatives

Types of sources considered for Tank Closure alternatives include past leaks, retrieval leaks, tank residuals, and ancillary equipment at 18 tank farms and planned discharges at six sets of cribs and trenches (ditches) associated with tank farm operations. These facilities are all in the 200-East and 200-West Areas.

M.3.1.1 Tank Farm Sources

Liquid and solid sources are considered for release analysis at the 18 HLW tank farms. Descriptions of the dimensions, configuration and closure systems for tank farms are presented in the *Tank System Closure and Facility D&D* [decontamination and decommissioning] *Data Package* (DOE 2003a).

Primary liquid sources are past leaks and retrieval leaks from 100- and 200-series tanks located at single-shell tank farms for all Tank Closure alternatives and ancillary equipment failure leaks at all tank farms and tank failure leaks at double-shell tank farms for Tank Closure Alternatives 1 and 2A for which tank closure does not occur.

For past leaks, 67 tanks are included in the analysis, and model parameters include volume of liquid, inventory of constituents, and time of occurrence of the leak. Volumes of liquid assumed for the purpose of analysis are those presented in the Hanlon waste tank summary report (Hanlon 2003). If a volume estimate is missing from the Hanlon report for a specific tank, an estimate of the smallest detectable leak volume of 30 cubic meters (8,000 gallons) is assumed for that tank. Inventory estimates for past leaks are developed from field investigation reports (FIRs) for tank farms B, BX, and BY (Knepp 2002); S and SX (CH2M HILL 2002); and T, TX, and TY (Myers 2005). Subsurface conditions reports are used for estimates of inventory for tank farms A, AX, and C (Wood et al. 2003) and U (Wood and Jones 2003). If an inventory estimate for a specific tank included in the Hanlon list is not presented in an FIR or subsurface conditions report, the inventory for that tank is estimated using the average concentration for leaks from that tank farm presented in the FIR or subsurface conditions report and the leak volume from the Hanlon report. Estimates of volume of leak and date of occurrence for the 67 tanks are presented in Table M–3. Estimates of date of occurrence are adopted from the FIRs, subsurface conditions reports,

and preliminary field studies (Jones et al. 2000, 2001). Estimates of quantities of constituents released with past leaks are presented in Appendix D of this environmental impact statement (EIS).

Table M–3. Summary of Estimates of Volumes and Dates for Past Leaks

Tank	Leak Volume (gallons)[a]	Date of Occurrence		Tank	Leak Volume (gallons)	Date of Occurrence
241-A-103	5,500	1956[b]		241-SX-104	6,000	1954[b]
241-A-104	2,500	1975[c]		241-SX-107	5,000	1964[f]
241-A-105	277,000	1963[c]		241-SX-108	35,000	1965[f]
241-AX-102	3,000	1965[b]		241-SX-109	10,000	1964[f]
241-AX-104	8,000	1965[b]		241-SX-110	5,500	1974[f]
241-B-101	8,000	1974[d]		241-SX-111	2,000	1973[f]
241-B-103	8,000	1945[b]		241-SX-112	30,000	1969[f]
241-B-105	8,000	1968[d]		241-SX-113	15,000	1962[f]
241-B-107	8,000	1966[d]		241-SX-114	8,000	1972[f]
241-B-110	10,000	1970[d]		241-SX-115	50,000	1964[f]
241-B-111	8,000	1945[b]		241-T-101	7,500	1969[g]
241-B-112	2,000	1945[b]		241-T-103	1,000	1973[g]
241-B-201	1,200	1966[c]		241-T-106	115,000	1973[g]
241-B-203	300	1966[c]		241-T-107	8,000	1944[b]
241-B-204	400	1966[c]		241-T-108	1,000	1944[b]
241-BX-101	8,000	1968[e]		241-T-109	1,000	1944[b]
241-BX-102	70,000	1951[e]		241-T-111	1,000	1944[b]
241-BX-108	2,500	1948[b]		241-TX-105	8,000	1949[b]
241-BX-110	8,000	1948[b]		241-TX-107	2,500	1977[g]
241-BX-111	8,000	1965[d]		241-TX-110	8,000	1949[b]
241-BY-103	5,000	1950[b]		241-TX-113	8,000	1949[b]
241-BY-105	8,000	1950[b]		241-TX-114	8,000	1949[b]
241-BY-106	8,000	1950[b]		241-TX-115	8,000	1949[b]
241-BY-107	15,100	1950[b]		241-TX-116	8,000	1949[b]
241-BY-108	5,000	1950[b]		241-TX-117	8,000	1949[b]
241-C-101	20,000	1946[b]		241-TY-101	1,000	1953[b]
241-C-110	2,000	1946[b]		241-TY-103	3,000	1971[g]
241-C-111	5,500	1946[b]		241-TY-104	1,400	1953[b]
241-C-201	550	1946[b]		241-TY-105	35,000	1960[g]
241-C-202	450	1946[b]		241-TY-106	20,000	1957[g]
241-C-203	400	1946[b]		241-U-101	30,000	1946[b]
241-C-204	350	1946[b]		241-U-104	55,000	1956[h]
241-S-104	24,000	1965[f]		241-U-110	8,100	1975[h]
				241-U-112	8,500	1946[b]

[a] Hanlon 2003.
[b] Anderson 1990.
[c] Wood et al. 2003.
[d] Jones et al. 2001.
[e] Knepp 2002.
[f] CH2M HILL 2002.
[g] Jones et al. 2000.
[h] Wood and Jones 2003.

U.S. Department of Energy (DOE) estimates that a volume of 15 cubic meters (4,000 gallons) would leak from each of the 149 single-shell tanks during waste retrieval (see Section E.1.2.2.5.2). For each tank farm, the retrieval leaks are assumed to occur simultaneously in calendar year 2018. Estimates of the inventory of constituents for retrieval leaks are developed by assuming that three volumes of sluicing liquid are required to entrain one volume of tank solids and that the solids have the composition of the

December 2002 estimate of the Best-Basis Inventory (BBI). The BBI is documented in the *Inventory and Source Term Data Package* (DOE 2003b). Estimates of quantities of constituents released in retrieval leaks are presented in Appendix D of this EIS.

Primary solid sources at tank farms are salt cake remaining in single-shell tanks under Tank Closure Alternatives 1 and 2A and grouted residuals in tanks and ancillary equipment under Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C.

For releases from salt cake, the release model proposed is the matrix solubility limited-release model described in Section M.2.2.2. The proposed value of solubility for the matrix is a literature estimate of the solubility of sodium nitrate: 920,000 grams per cubic meter (Weast and Selby 1967). The mass and volume of waste in each tank farm and inventory of constituents are those documented in the *Inventory and Source Term Data Package* (DOE 2003b). For Tank Closure Alternative 1, the residual inventory remaining in each tank at the time of failure (time of loss of administrative or institutional control) is the total inventory of the BBI. For Tank Closure Alternative 2A, the inventory remaining in each tank at the time of failure is 1 percent of the BBI. The magnitude and timing of infiltration for Tank Closure Alternatives 1 and 2A are summarized in Table M–4.

Table M–4. Tank Closure Alternatives 1 and 2A Infiltration Sequence Description

Location Conditions	Tank Closure Alternative 1	Tank Closure Alternative 2A	Infiltration Value (millimeters per year)
	Year at Start of Infiltration Value		
Pre-Hanford	1940	1940	3.5
Disturbed conditions	1948	1948	100
Post–barrier design life	2108	2194	3.5

For releases from grouted residuals in HLW tanks and ancillary equipment, the proposed release model is the partition-limited, convective flow release model described in Section M.2.2.1. The inventory is assumed to reside in the bottom meter of the tank with a short diffusion distance in the downward vertical direction and a large diffusion distance in the upward vertical direction. Dimensions of the tank are those described in the *Tank System Closure and Facility D&D Data Package* (DOE 2003a), and the constituent inventories are fractions of the BBI appropriate for each alternative with the BBI specified in the *Inventory and Source Term Data Package* (DOE 2003b).

Primary remaining parameters of the model are the rate of recharge and the retardation factor defined in conjunction with Equation M–5. The magnitude and timing of the sequence of infiltration for Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C are summarized in Table M–5. For Alternatives 2B, 3A, 3B, 3C, 4, and 6C, modified Resource Conservation and Recovery Act (RCRA) Subtitle C barriers with a design life of 500 years would be placed over the tank farms. Hanford barriers with a design life of 1,000 years would be placed over the tank farms for Tank Closure Alternative 5. Values of distribution coefficient used in the calculation of retardation factor are presented in Tables M–6 (radiological constituents) and M–7 (chemical constituents) and are those recommended for grout (DOE 2005) or reported in nationwide surveys of soil (Beyeler et al. 1999; Sheppard and Thibault 1990).

Table M–5. Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C Infiltration Sequence Description

Location Conditions	Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, and 6C	Tank Closure Alternative 5	Infiltration Value (millimeters per year)
	Year at Start of Infiltration Value		
Pre-Hanford	1940	1940	3.5
Disturbed conditions	1948	1948	100
Barrier design life	2050	2050	0.5
Post–barrier design life	2550	3050	3.5

Table M–6. Values of Distribution Coefficient for Radiological Constituents in Hanford Grout

Constituent	Distribution Coefficient (milliliters per gram)	Source
Hydrogen	0	DOE 2005
Carbon	5	DOE 2005
Potassium	15	Sheppard and Thibault 1990
Strontium	15	DOE 2005
Zirconium	600	Sheppard and Thibault 1990
Technetium	1	DOE 2005
Iodine	50	DOE 2005
Cesium	280	DOE 2005
Gadolinium	5	Sheppard and Thibault 1990
Thorium	3,200	Beyeler et al. 1999
Uranium	35	DOE 2005
Neptunium	15	DOE 2005
Plutonium	550	DOE 2005
Americium	1,900	Beyeler et al. 1999

Table M–7. Values of Distribution Coefficient for Chemical Constituents in Hanford Grout

Constituent	Distribution Coefficient (milliliters per gram)	Source
Arsenic	4×10^{2}	Sheppard and Thibault 1990
Boron	0	Sheppard and Thibault 1990
Cadmium	8×10^{1}	Sheppard and Thibault 1990
Chromium	0	DOE 2005
Fluoride	0	Sheppard and Thibault 1990
Lead	8×10^{1}	DOE 2005
Manganese	5×10^{1}	Beyeler et al. 1999
Mercury	1×10^{1}	DOE 2005
Molybdenum	1×10^{1}	Beyeler et al. 1999
Nickel	4×10^{2}	Beyeler et al. 1999
Nitrate	0	DOE 2005
Silver	9×10^{1}	Beyeler et al. 1999
Strontium	1×10^{1}	Sheppard and Thibault 1990
Total uranium	6×10^{-1}	Sheppard and Thibault 1990
Acetonitrile	0	DOE 2005
Benzene	1	DOE 2005
Butanol	3	DOE 2005
Polychlorinated biphenols	1.7×10^{5}	DOE 2005
2,4,6-Trichlorophenol	3.8×10^{-1}	DOE 2005

Table M–7. Values of Distribution Coefficient for Chemical Constituents in Hanford Grout *(continued)*

Constituent	Distribution Coefficient (milliliters per gram)	Source
1,2-Dichloroethane	0	Sheppard and Thibault 1990
1,4-Dioxane	0	Sheppard and Thibault 1990
Carbon tetrachloride	0	Sheppard and Thibault 1990
Dichloromethane	0	Sheppard and Thibault 1990
Hydrazine	0	Sheppard and Thibault 1990
Vinyl chloride	0	Sheppard and Thibault 1990
Trichloroethylene	0	Sheppard and Thibault 1990

M.3.1.2 Tank Closure Waste Forms

Primary waste forms associated with tank farm closure are: ILAW glass, bulk vitrification glass, bulk vitrification castable refractory block, cast stone, steam reforming solids, Effluent Treatment Facility (ETF) secondary grout, sulfate grout, retired melters, and contaminated soil. A primary constituent of ETF secondary waste is iodine-129 recovered from offgases of thermal treatment processes (vitrification, bulk vitrification, and steam reforming).

For ILAW glass and glass in retired melters, the fractional release rate model is applied. The value of the fractional release rate is 2.8×10^{-8} (gram per gram) per year based on detailed analysis using the STORM [Subsurface Transport Over Reactive Multiphases] model (Mann et al. 2003). For bulk vitrification glass, the fractional release rate model is applied. The value of the fractional release rate is 1.0×10^{-8} (gram per gram) per year based on detailed analysis using the STORM model (Mann et al. 2003). During the bulk vitrification process, a portion of the feed technetium is volatilized and trapped in refractory above the glass surface. For this material, the partition-limited, convective flow release model with value of zero for distribution coefficient of technetium is applied. The refractory is porous ceramic material and research has demonstrated that technetium volatilized during bulk vitrification collects in this material (Mann et al. 2003). The fraction of technetium present in the original melt that resides in the castable refractory block has been measured and an upper limit of 6.5 percent has been established (peer review). For cast stone and ETF secondary and sulfate grout waste forms, the cylindrical geometry, diffusion limited-release model described in Section M.2.2.4 is applied. Values of aqueous diffusivity are based on ion conductivity data (Weast and Selby 1966:5-111) with values for key species iodate, pertechnetate, and nitrate of 1.1×10^{-5}, 1.5×10^{-5}, and 1.9×10^{-5} square centimeters per second, respectively. The porosity of grout is estimated as 0.43 based on a crystal density of 2.65 grams per cubic centimeter for natural silicates (Freeze and Cherry 1979:337; Mason and Berry 1968) and bulk density of grout of 1.5 grams per cubic centimeter (DOE 2003c:6-100). Because the value of effective porosity has not been established for site conditions, the value of total porosity is applied for effective porosity as a conservative limit of release rates. Site-specific tests of effective diffusivity of nitrate in grout are reported as 3×10^{-8} square centimeters per second (Lockrem 2005). Effective diffusivity is defined as the product of tortuosity and aqueous diffusivity divided by the retardation factor. Assuming that nitrate does not adsorb onto the grout, these data imply a site-specific value of tortuosity of 1.6×10^{-3}. Using the definition of effective diffusivity and *Technical Guidance Document*–recommended values of effective diffusivity (DOE 2005) implied values of the distribution coefficient for technetium and iodine in grout are 1 and 50 milliliters per gram, respectively. Values of aqueous diffusivity and effective diffusivity for grout consistent with the *Technical Guidance Document* (DOE 2005) are summarized in Tables M–8 and M–9 for radiological and chemical constituents, respectively. The experimental program for characterization of steam reforming solids has established operability of the solidification process (THOR Treatment Technologies 2002) and characterization of release mechanisms and rates (Lorier, Pareizs, and Jantzen 2005; McGrail et al. 2003a, 2003b) is under way but has not yielded a complete basis for long-term performance assessment. In addition, alternate forms of the final product are under investigation (Jantzen

2006). For the purpose of long-term performance assessment for this *TC & WM EIS*, steam reforming solids are assumed to have the form of a finely divided solid. In light of the above considerations, an upper limit on the rate of release of constituents from steam reforming solids was developed based on the limited availability of water and the stoichiometry of hydrolysis of steam reforming solids. Research has identified nepheline (Na_2AlSiO_4) as the primary component of steam reforming solids (McGrail et al. 2003a). For a hydrolysis reaction requiring two moles of water for each mole of nepheline and water infiltration rates of 0.5 and 0.9 millimeters per year for the cap design period of 500 years and post-design periods, complete dissolution of finely divided steam reforming solids would occur within 1890 years. This corresponds to an equivalent solubility of 3.95×10^6 grams per cubic meter for use on the waste matrix solubility limited release model. For contaminated soil disposed of at the River Protection Project Disposal Facility (RPPDF), the partition-limited, convective flow model is applied. Values of distribution factor for soil are those recommended in the *Technical Guidance Document* (DOE 2005) for Hanford vadose zone sediments or in nationwide surveys of soil (Beyeler et al. 1999; Sheppard and Thibault 1990). These values are summarized in Tables M–10 and M–11 for radiological and chemical constituents, respectively.

Table M–8. Values of Aqueous and Effective Diffusivity for Radiological Constituents in Hanford Grout

Constituent	Aqueous Diffusivity (square centimeters per second)	Effective Diffusivity (square centimeters per second)
Hydrogen	9.3×10^{-5}	1.5×10^{-7}
Carbon	9.2×10^{-6}	7.9×10^{-10}
Potassium	2.0×10^{-5}	5.8×10^{-10}
Strontium	7.9×10^{-6}	2.3×10^{-10}
Zirconium	2.0×10^{-5}	1.5×10^{-11}
Technetium	1.5×10^{-5}	5.2×10^{-9}
Iodine	1.1×10^{-5}	1.0×10^{-10}
Cesium	2.1×10^{-5}	3.3×10^{-11}
Gadolinium	6.0×10^{-6}	5.1×10^{-10}
Thorium	4.3×10^{-6}	6.0×10^{-13}
Uranium	4.3×10^{-6}	5.5×10^{-11}
Neptunium	4.3×10^{-6}	1.3×10^{-10}
Plutonium	4.3×10^{-6}	3.5×10^{-12}
Americium	4.3×10^{-6}	1.0×10^{-12}

Table M–9. Values of Aqueous and Effective Diffusivity for Chemical Constituents in Hanford Grout

Constituent	Aqueous Diffusivity (square centimeters per second)	Effective Diffusivity (square centimeters per second)
Arsenic	9.05×10^{-6}	1.03×10^{-11}
Boron	1.25×10^{-5}	2.00×10^{-8}
Cadmium	7.19×10^{-6}	4.08×10^{-11}
Chromium	1.13×10^{-5}	1.81×10^{-8}
Fluoride	1.48×10^{-5}	2.36×10^{-8}
Lead	9.45×10^{-6}	5.36×10^{-11}
Manganese	7.12×10^{-6}	6.45×10^{-11}
Mercury	8.47×10^{-6}	3.75×10^{-10}
Molybdenum	1.98×10^{-5}	8.79×10^{-10}
Nickel	6.66×10^{-7}	7.58×10^{-13}
Nitrate	1.90×10^{-5}	3.04×10^{-8}
Silver	1.65×10^{-5}	8.32×10^{-11}
Strontium	7.91×10^{-6}	3.50×10^{-10}
Total uranium	4.26×10^{-6}	2.19×10^{-9}

Table M–9. Values of Aqueous and Effective Diffusivity for Chemical Constituents in Hanford Grout *(continued)*

Constituent	Aqueous Diffusivity (square centimeters per second)	Effective Diffusivity (square centimeters per second)
Acetonitrile	8.77×10^{-7}	1.40×10^{-9}
Benzene	6.38×10^{-6}	2.26×10^{-9}
Butanol	6.26×10^{-6}	8.69×10^{-10}
Polychlorinated biphenols	3.71×10^{-6}	9.93×10^{-15}
2,4,6-Trichlorophenol	5.00×10^{-6}	3.43×10^{-9}
1,2-Dichloroethane	6.84×10^{-6}	1.09×10^{-8}
1,4-Dioxane	6.54×10^{-6}	1.05×10^{-8}
Carbon tetrachloride	6.06×10^{-6}	9.70×10^{-9}
Dichloromethane	7.75×10^{-6}	1.24×10^{-8}
Hydrazine	1.25×10^{-5}	1.99×10^{-8}
Vinyl chloride	7.48×10^{-6}	1.20×10^{-8}
Trichloroethylene	6.33×10^{-6}	1.01×10^{-8}

Table M–10. Values of Distribution Coefficient for Radiological Constituents for Contaminated Soil

Constituent	Distribution Coefficient (milliliters per gram)	Source
Hydrogen	0	DOE 2005
Carbon	4	DOE 2005
Potassium	15	Sheppard and Thibault 1990
Strontium	10	DOE 2005
Zirconium	600	Sheppard and Thibault 1990
Technetium	0	DOE 2005
Iodine	0	DOE 2005
Cesium	80	DOE 2005
Gadolinium	5	Sheppard and Thibault 1990
Thorium	3,200	Beyeler et al. 1999
Uranium	0.6	DOE 2005
Neptunium	2.5	DOE 2005
Plutonium	150	DOE 2005
Americium	1,900	Beyeler et al. 1999

Table M–11. Values of Distribution Coefficient for Chemical Constituents for Contaminated Soils

Constituent	Distribution Coefficient (milliliters per gram)	Source
Arsenic	4×10^{2}	Sheppard and Thibault 1990
Boron	0	Sheppard and Thibault 1990
Cadmium	8×10^{-1}	Sheppard and Thibault 1990
Chromium	0	DOE 2005
Fluoride	0	Sheppard and Thibault 1990
Lead	8×10^{1}	DOE 2005
Manganese	5×10^{1}	Beyeler et al. 1999
Mercury	1×10^{1}	DOE 2005
Molybdenum	1×10^{1}	Beyeler et al. 1999
Nickel	4×10^{2}	Beyeler et al. 1999
Nitrate	0	DOE 2005
Silver	9×10^{1}	Beyeler et al. 1999
Strontium	1×10^{1}	Sheppard and Thibault 1990
Total uranium	6×10^{-1}	Sheppard and Thibault 1990

Table M–11. Values of Distribution Coefficient for Chemical Constituents for Contaminated Soils *(continued)*

Constituent	Distribution Coefficient (milliliters per gram)	Source
Acetonitrile	0	DOE 2005
Benzene	1	DOE 2005
Butanol	3	DOE 2005
Polychlorinated biphenols	1.7×10^{5}	DOE 2005
2,4,6-Trichlorophenol	3.8×10^{-1}	Sheppard and Thibault 1990
1,2-Dichloroethane	0	Sheppard and Thibault 1990
1,4-Dioxane	0	Sheppard and Thibault 1990
Carbon tetrachloride	0	Sheppard and Thibault 1990
Dichloromethane	0	Sheppard and Thibault 1990
Hydrazine	0	Sheppard and Thibault 1990
Vinyl chloride	0	Sheppard and Thibault 1990
Trichloroethylene	0	Sheppard and Thibault 1990

M.3.1.3 Cribs and Trenches (Ditches)

Sources at cribs and trenches (ditches) are liquid sources modeled as pulse releases characterized by liquid volume, source area, and time of occurrence. Values for these model parameters are those reported in the Hanford Soil Inventory Model (SIM) database and are summarized in Appendix D of this EIS.

M.3.2 FFTF Decommissioning Alternatives

Under FFTF Decommissioning Alternative 1, the FFTF Reactor Containment Building (RCB, Building 405), and the other buildings within the 400 Area Property Protected Area, would be maintained under administrative controls for 100 years through 2107. After 2107, remaining waste would be available for release to the environment.

FFTF Decommissioning Alternative 2 calls for in-place closure of FFTF. The main RCB and the two immediately adjacent support facilities (Buildings 491E and 491W), all above-grade structures would be dismantled. Demolition waste would be consolidated in the below-grade spaces or disposed of at an IDF. Below-grade spaces would be filled with demolition waste and stabilized with fill material (grout) to immobilize hazardous materials and minimize future subsidence. A modified RCRA Subtitle C barrier would be constructed over the filled area with a design life of 500 years.

FFTF Decommissioning Alternative 3 describes removal and clean closure of FFTF. All above-grade structures around the main RCB and the immediately adjacent support facilities would be dismantled, and the contaminated demolition debris would be disposed of at an IDF. All other radioactively contaminated equipment and hazardous materials (including asbestos and lead shielding) would be removed for disposal at an IDF. Contaminated demolition debris would be removed to an IDF, and the vacated spaces backfilled, compacted, contoured, and revegetated. All radioactive and/or hazardous material, wood and large steel components would be removed. The surface would be contoured, and revegetated; no barrier would be required.

Consistent with this description of the three FFTF Decommissioning alternatives, the partition-limited, convective flow model is applied. The magnitude and timing of infiltration sequences for FFTF Decommissioning Alternatives 1, 2, and 3 are presented in Tables M–12, M–13, and M–14, respectively. The values of infiltration rate are based on chloride mass balance and lysimeter tests and are those recommended in the *Technical Guidance Document* (DOE 2005).

Table M–12. FFTF Decommissioning Alternative 1 Infiltration Sequence Description

Location Conditions	Year at Start of Infiltration Value	Infiltration Value (millimeters per year)
Pre-Hanford	1940	3.5
Disturbed conditions	1980	50
End of institutional controls	2107	3.5

Key: Fast Flux Test Facility.

Table M–13. FFTF Alternative 2 Infiltration Sequence Description

Location Conditions	Year at Start of Infiltration Value	Infiltration Value (millimeters per year)
Pre-Hanford	1940	3.5
Disturbed conditions	1980	50
Barrier design life	2022	0.5
Post–barrier design life	2522	3.5

Key: Fast Flux Test Facility.

Table M–14. FFTF Decommissioning Alternative 3 Infiltration Sequence Description

Location Conditions	Year at Start of Infiltration Value	Infiltration Value (millimeters per year)
Pre-Hanford	1940	3.5
Disturbed conditions	1980	50
End of institutional controls	2107	3.5

Key: Fast Flux Test Facility.

M.3.3 Waste Management Alternatives

Primary facilities considered in Waste Management alternatives are one or two IDFs, the RPPDF, and trenches 31 and 34 at low-level radioactive waste burial ground (LLBG) 218-W-5.

M.3.3.1 Low-Level Radioactive Waste Burial Facilities

Sources at low-level radioactive waste (LLW) disposal facilities, including LLBG 218-W-5, are modeled as contaminated soil and debris. For contaminated soil sources, the partitioning limited, convective flow model is applied with soil type distribution coefficients presented in Tables M–10 and M–11. For stabilized waste, the cylindrical diffusion limited-release model is applied with effective diffusivities summarized in Tables M–8 and M–9.

Under Waste Management Alternative 1**,** LLW, mixed low-level radioactive waste (MLLW), and transuranic waste will be processed at the Central Waste Complex for disposal in LLBG 218-W-5 (lined) trenches 31 and 34. These trenches will operationally close in 2035. As discussed in Appendices D and S of this EIS, a barrier would not be placed over LLBG 218-W-5, including trenches 31 and 34, in 2035. The infiltration sequence used in modeling is described in Table M–15.

Table M–15. Waste Management Alternative 1 Infiltration Sequence Description for LLBG 218-W-5, Trenches 31 and 34

Location Conditions	Year at Start of Infiltration Value	Infiltration Value (millimeters per year)
Pre-Hanford	1940	3.5
Disturbed conditions	1986	50
Post–barrier design life	2086	3.5

Key: LLBG=low-level radioactive waste burial ground.

M.3.3.2 Integrated Disposal Facility Waste Forms

Characteristics of the primary and secondary tank closure waste forms proposed for disposal at an IDF are those described in Section M.3.1.2. The onsite non–Comprehensive Environmental Response, Compensation, and Liability Act (non-CERCLA) and waste management secondary wastes are modeled as grout waste forms with the characteristics described in Section M.3.1.2.

Waste Management Alternatives 2 and 3 include construction, operation, deactivation, closure, and postclosure care of IDF-East for tank, onsite-generated non-CERCLA, FFTF decommissioning, waste management, and offsite-generated LLW and MLLW. Under Waste Management Alternative 3, onsite-generated non-CERCLA, FFTF decommissioning, waste management, and offsite-generated LLW and MLLW would be disposed of in an IDF to be constructed in the 200-West Area (IDF-West), while tank LLW and MLLW would be disposed of in IDF-East. Three disposal groups were analyzed under these alternatives. Disposal Group 1 analyzes the operational completion date of 2050, with a barrier placed over IDF with a design life of 500 years. Disposal Group 2 analyzes the operational completion date of 2100, with a barrier placed over IDF with a design life of 500 years. Disposal Group 3 analyzes the operational completion date of 2165, with a barrier placed over IDF with a design life of 500 years. The magnitude and timing of the infiltration sequence for Waste Management Alternatives 2 and 3 are presented in Table M–16.

Table M–16. Waste Management Alternatives 2 and 3 Infiltration Sequence Description 200-East (West) Area Integrated Disposal Facility

Location Conditions	Disposal Group 1	Disposal Group 2	Disposal Group 3	IDF-East	IDF-West
	Year at Start of Infiltration Value			Infiltration Value (millimeters per year)	
Pre-Hanford	1940	1940	1940	0.9	3.5
Barrier design life	2050	2100	2165	0.5	0.5
Post–barrier design life	2550	2600	2665	0.9	3.5

Key: IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

M.4 RESULTS

M.4.1 Tank Closure Alternatives

M.4.1.1 Past Leaks from Cribs and Trenches (Ditches)

All Tank Closure alternatives are analyzed for the same constituent release to the vadose zone from past leaks from HLW tanks and discharges from cribs and trenches (ditches). Figures M–6 through M–11 demonstrate the total release of radiological and chemical constituents for the 10,000-year modeling period.

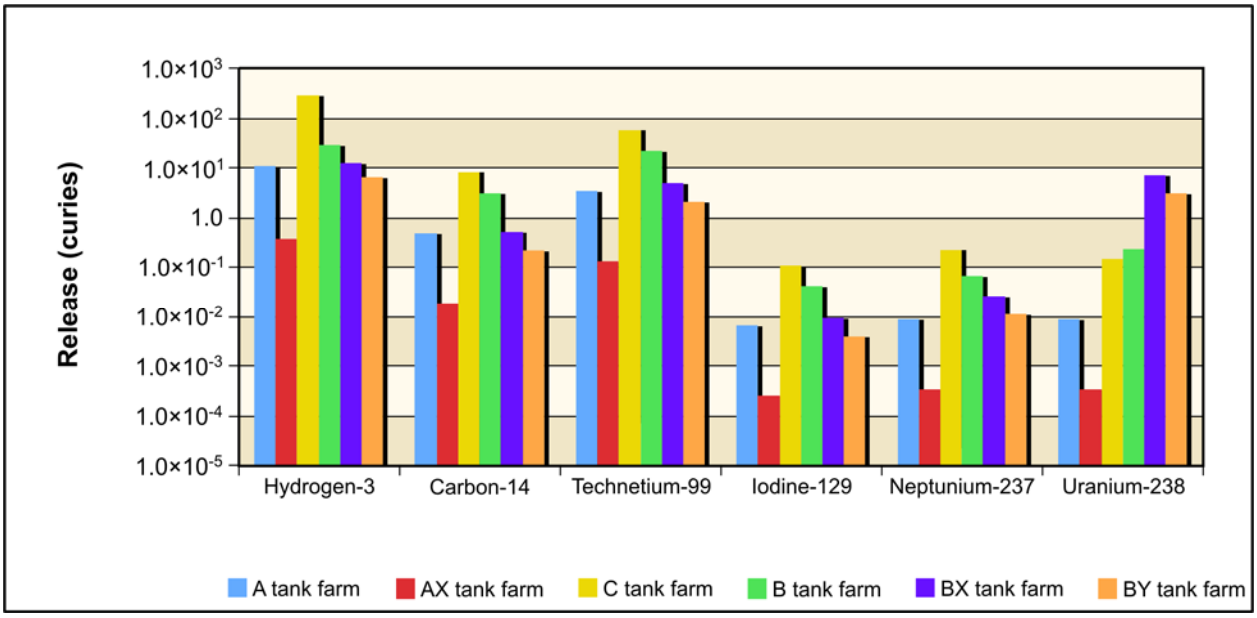


Figure M–6. Radiological Releases to Vadose Zone from 200-East Area Tank Farm Past Leaks

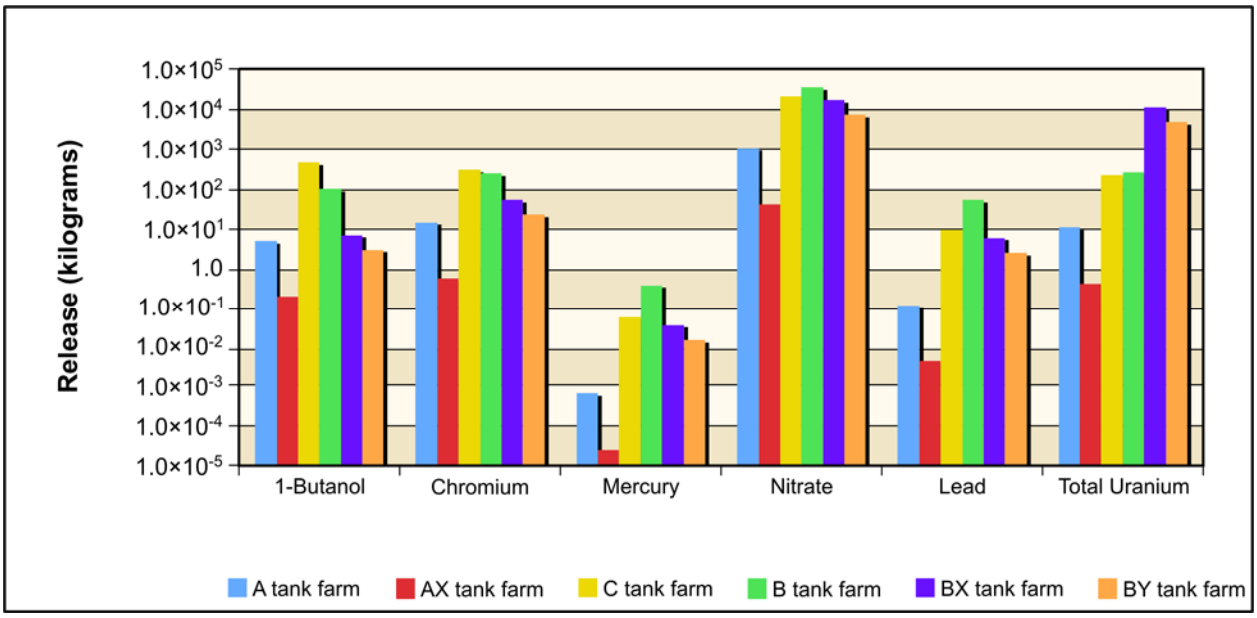


Figure M–7. Chemical Releases to Vadose Zone from 200-East Area Tank Farm Past Leaks

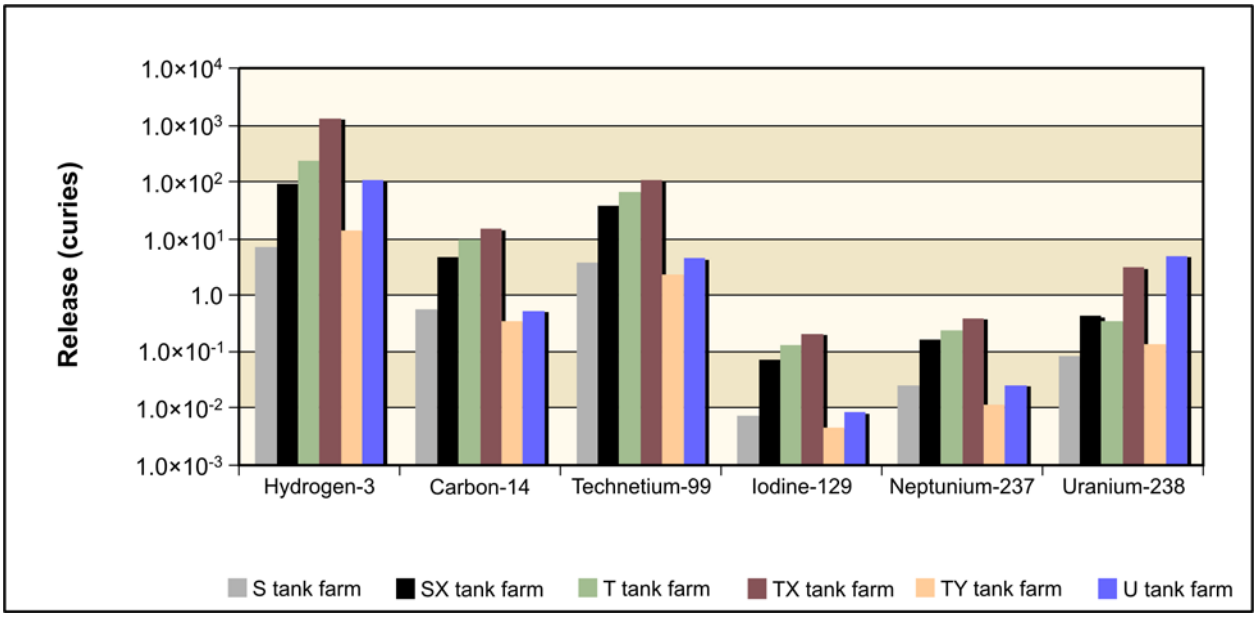


Figure M–8. Radiological Releases to Vadose Zone from 200-West Area Tank Farm Past Leaks

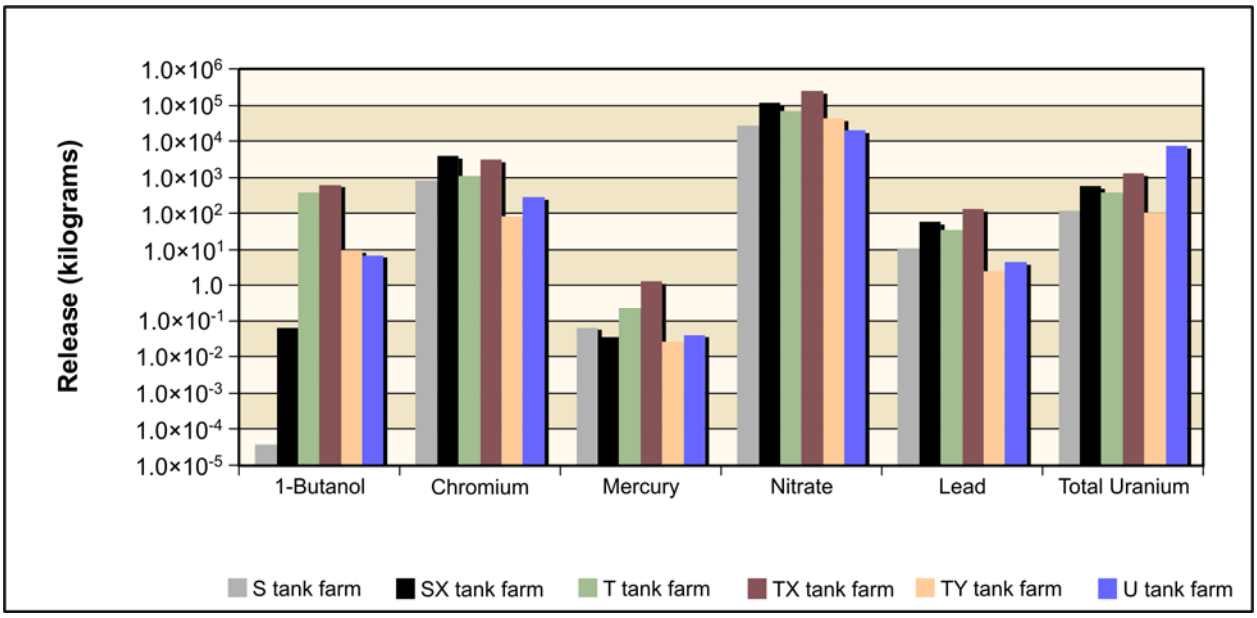


Figure M–9. Chemical Releases to Vadose Zone from 200-West Area Tank Farm Past Leaks

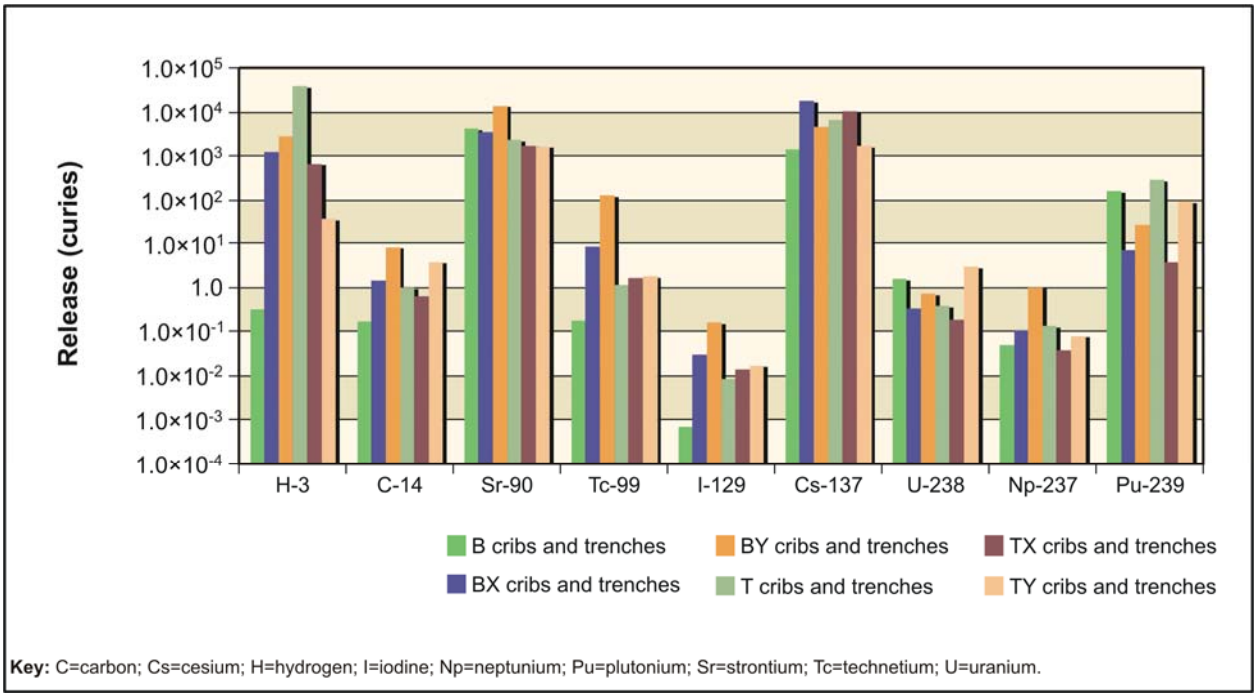


Figure M–10. Alternative Cribs and Trenches (Ditches) Radiological Releases to Vadose Zone

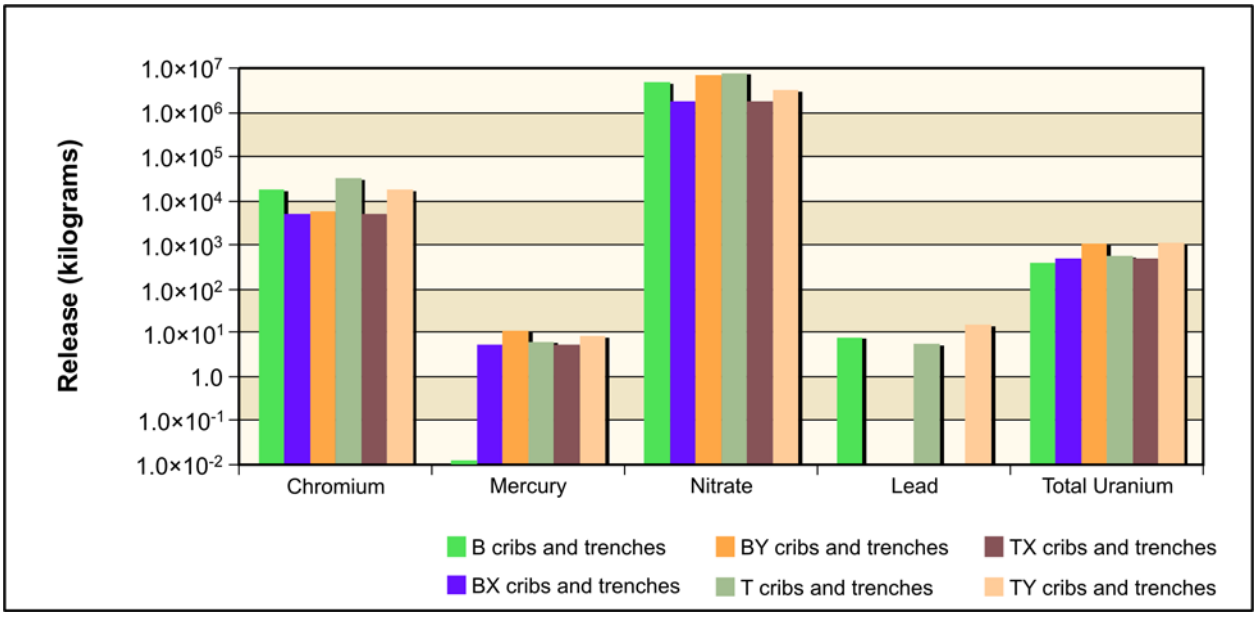


Figure M–11. Alternative Cribs and Trenches (Ditches) Chemical Releases to Vadose Zone

M.4.1.2 Releases from Other Sources in the Tank Farms

Releases from other sources related to the HLW tanks, including tank residuals, retrieval leaks, and ancillary equipment, were analyzed together. The amount of constituent released to the vadose zone is related to the activities under each Tank Closure alternative. Under Tank Closure Alternatives 6A and 6B, all tanks farms would be closed to a clean state by removing the tanks, ancillary equipment, and soil to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. Therefore, releases from other sources related to the HLW tanks were not analyzed.

Under Tank Closure Alternative 1, tank farms would be maintained in the current condition indefinitely but, for the purpose of analysis, are assumed to fail after an institutional control period of 100 years. At this time, the salt cake in single-shell tanks is assumed available for leaching into the vadose zone, and the liquid contents of double-shell tanks are assumed to be discharged directly to the vadose zone. Figures M–12 through M–17 indicates the constituent release estimated under Tank Closure Alternative 1.

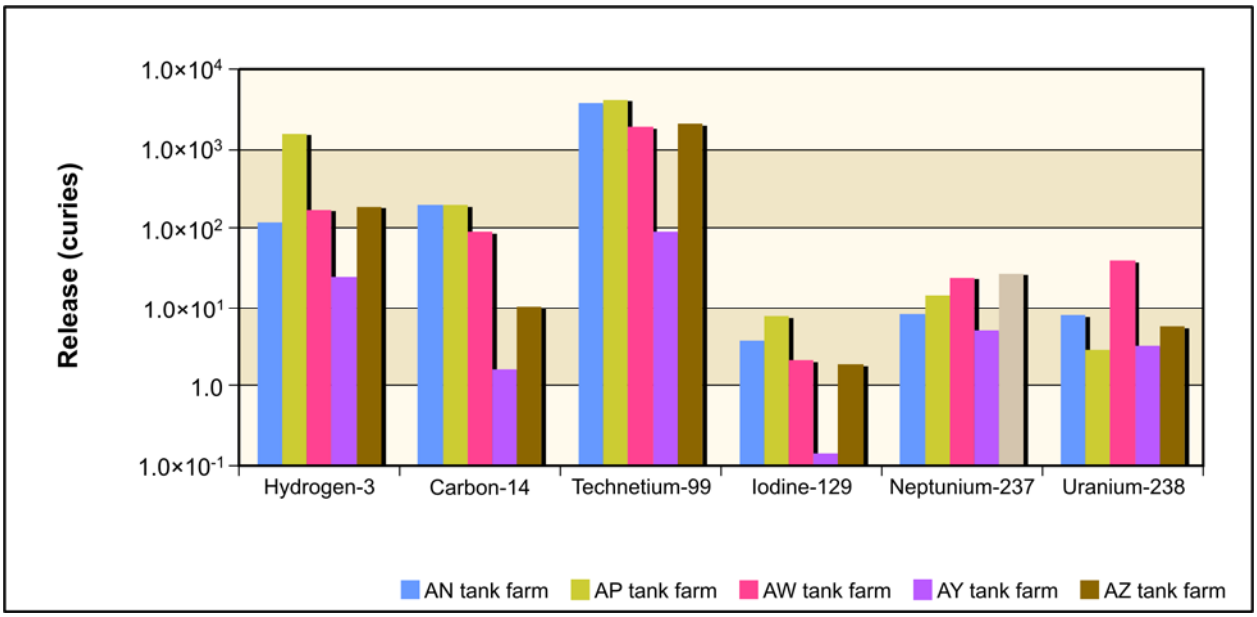


Figure M–12. Tank Closure Alternative 1 Radiological Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

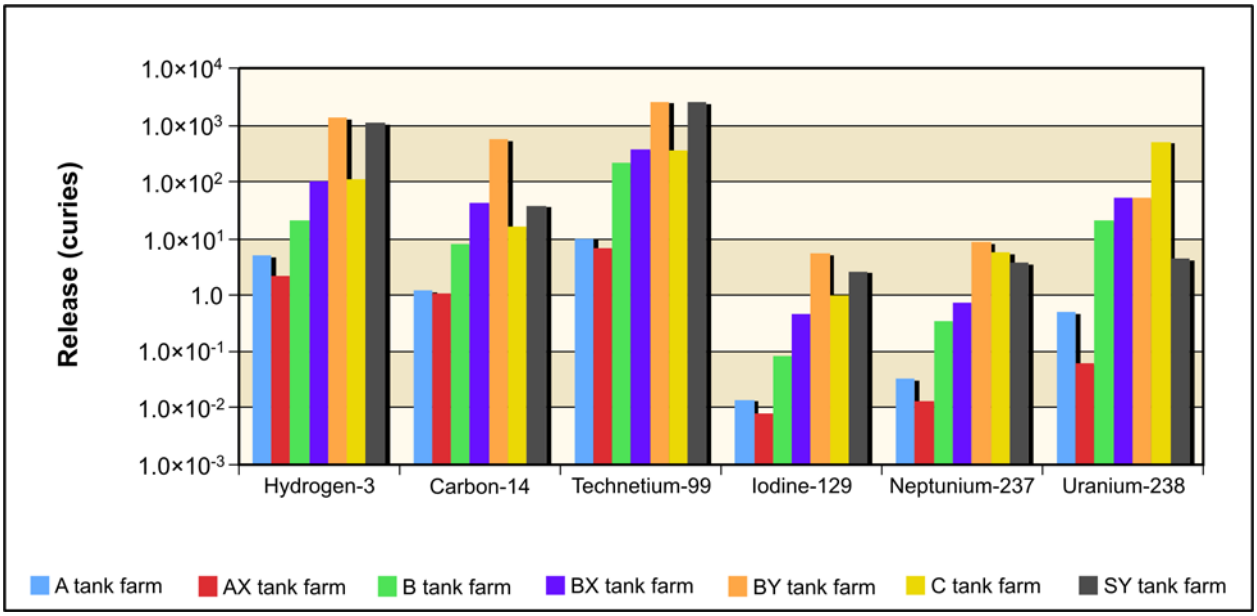


Figure M–13. Tank Closure Alternative 1 Radiological Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

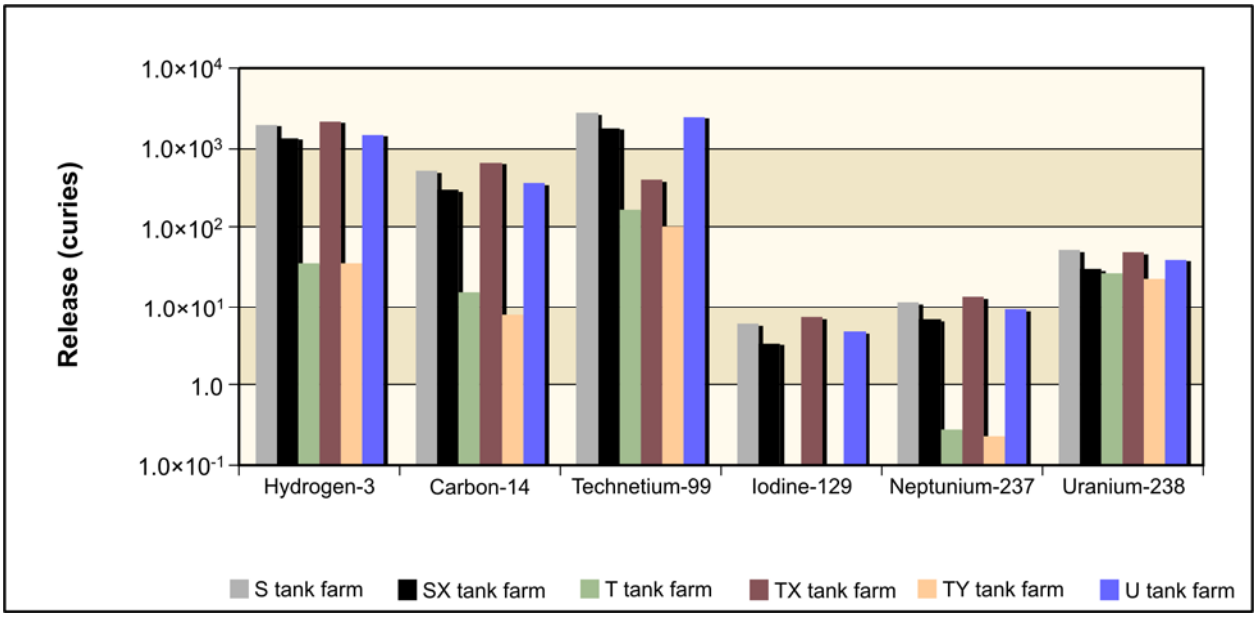


Figure M–14. Tank Closure Alternative 1 Radiological Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

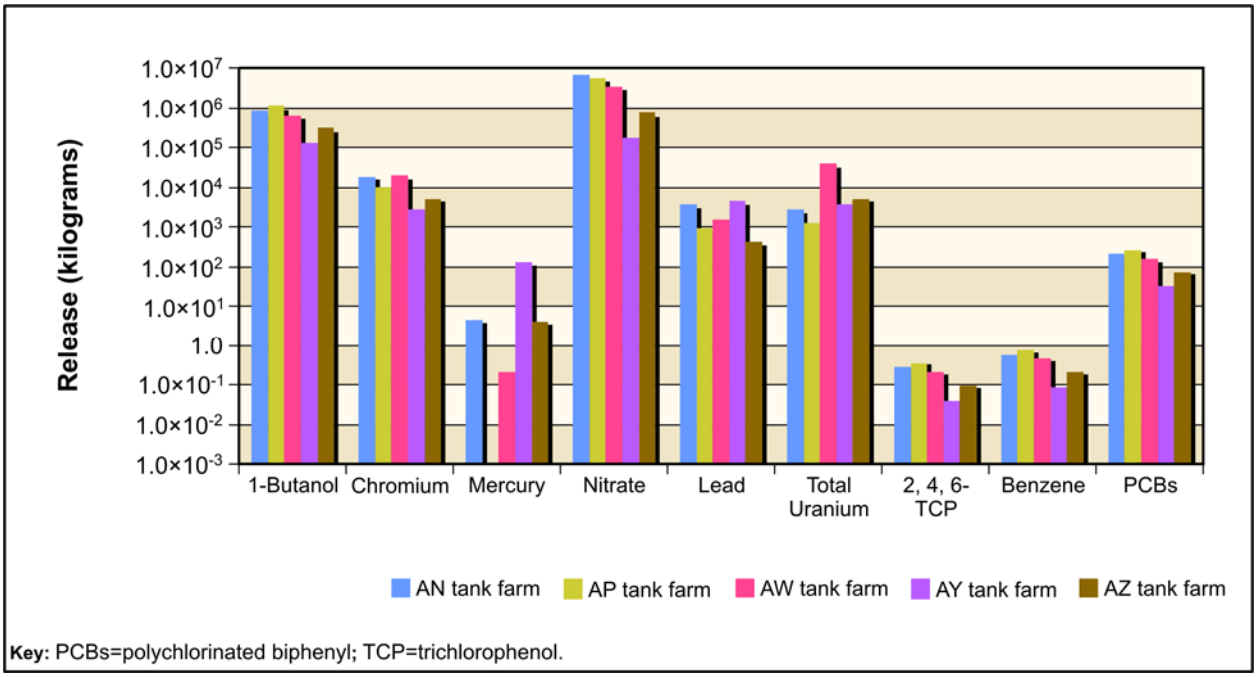


Figure M–15. Tank Closure Alternative 1 Chemical Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

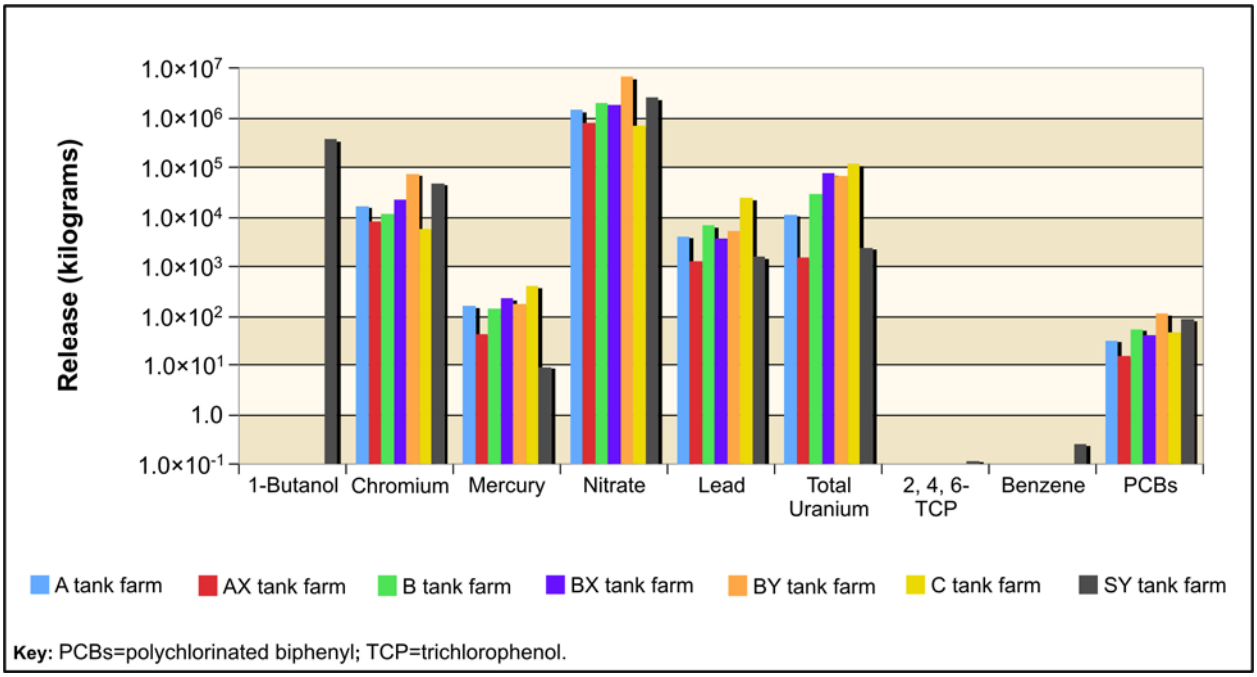


Figure M–16. Tank Closure Alternative 1 Chemical Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

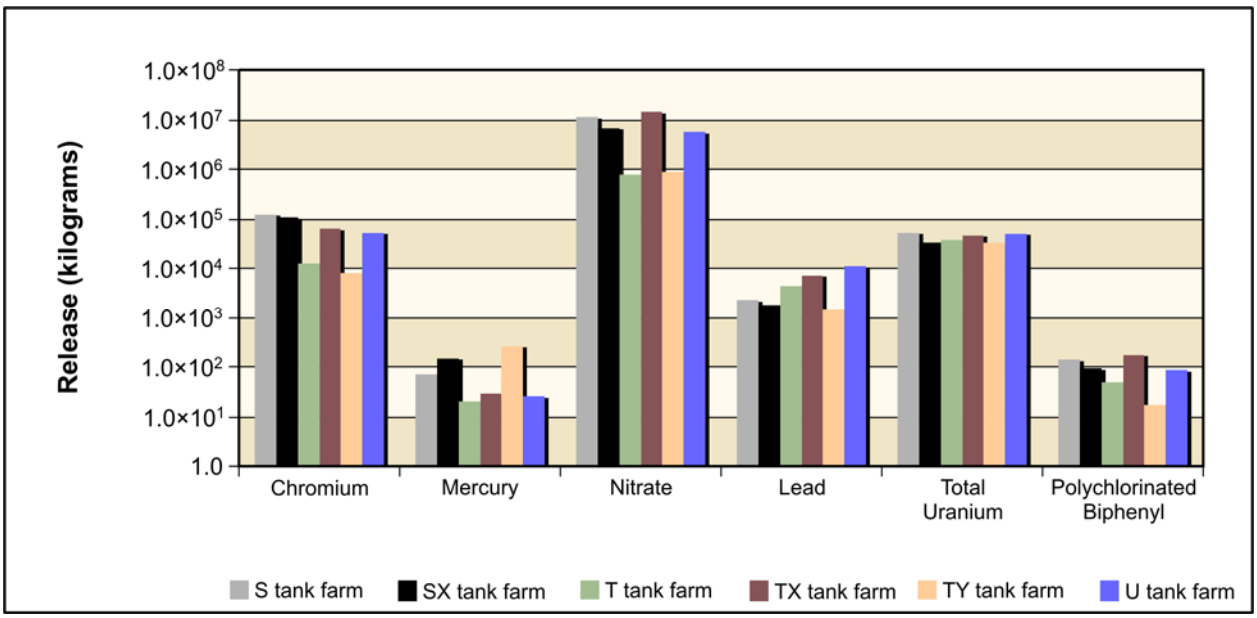


Figure M–17. Tank Closure Alternative 1 Chemical Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

Under Tank Closure Alternative 2A, tank waste would be retrieved to a volume corresponding to 99 percent retrieval, but residual material in tanks would not be stabilized. After an institutional control period of 100 years, the salt cake in tanks is assumed available for dissolution in infiltrating water. Potential releases to the vadose zone under Tank Closure Alternative 2A are indicated in Figures M–18 through M–23.

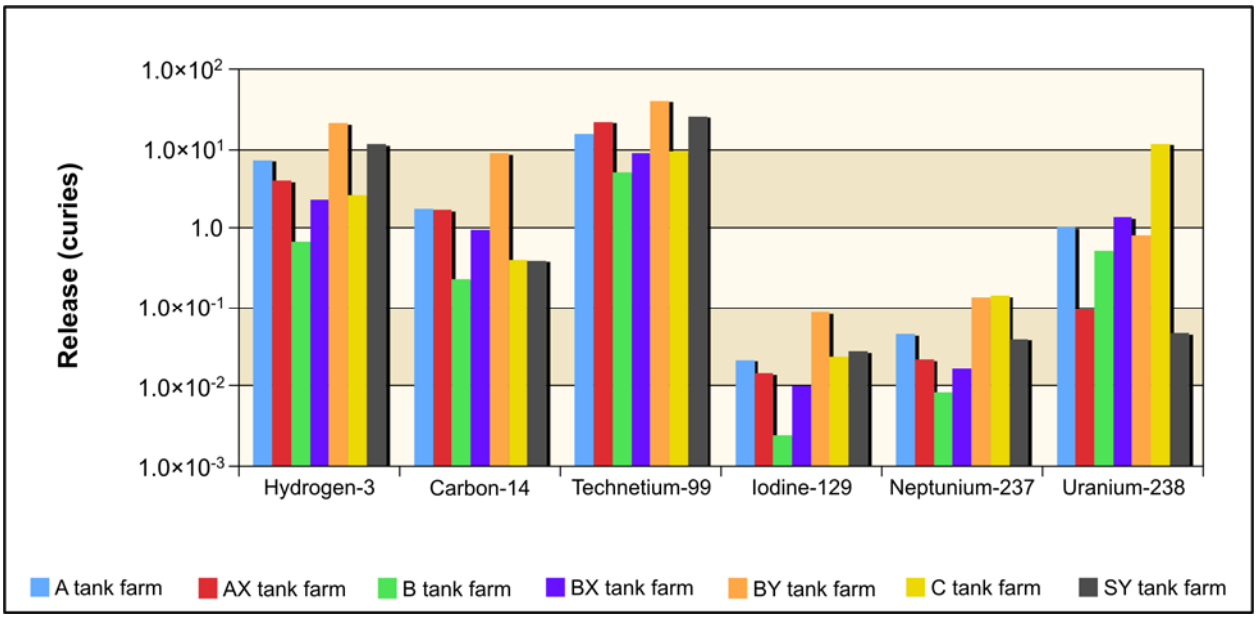


Figure M–18. Tank Closure Alternative 2A Radiological Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

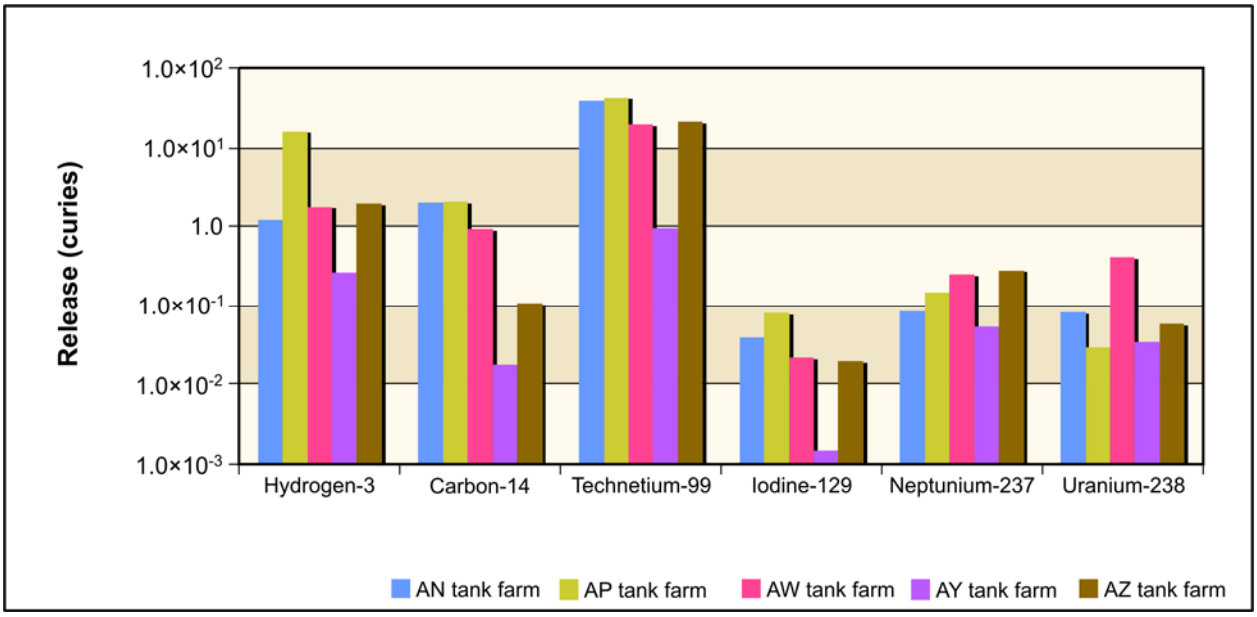


Figure M–19. Tank Closure Alternative 2A Radiological Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

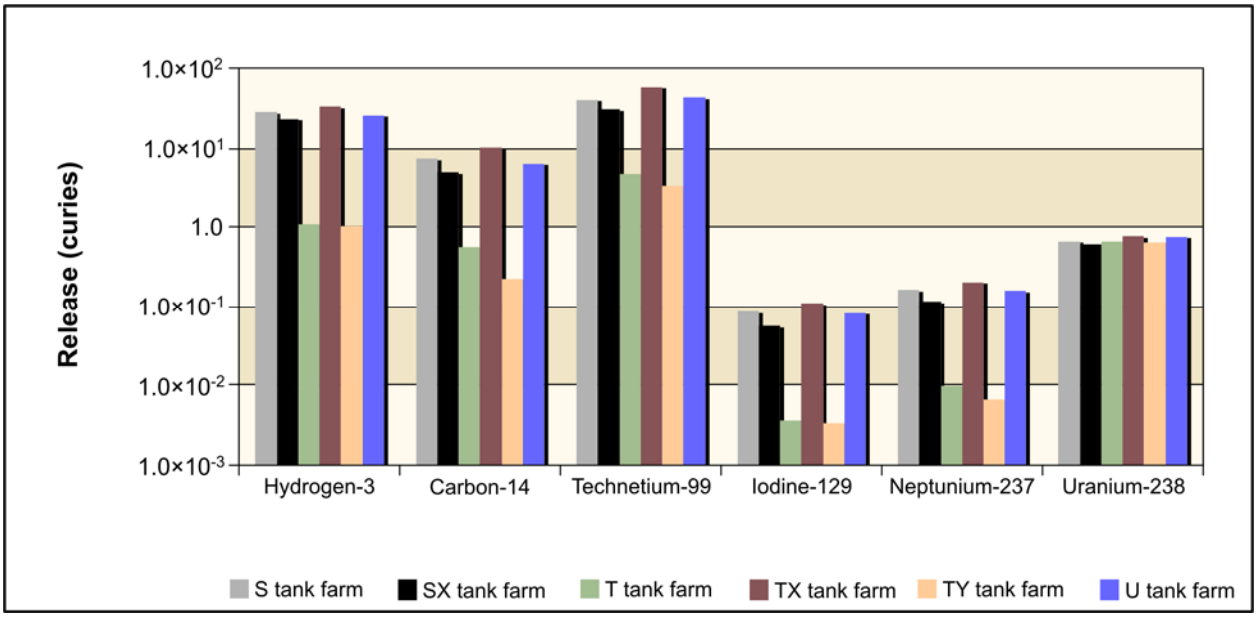


Figure M–20. Tank Closure Alternative 2A Radiological Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

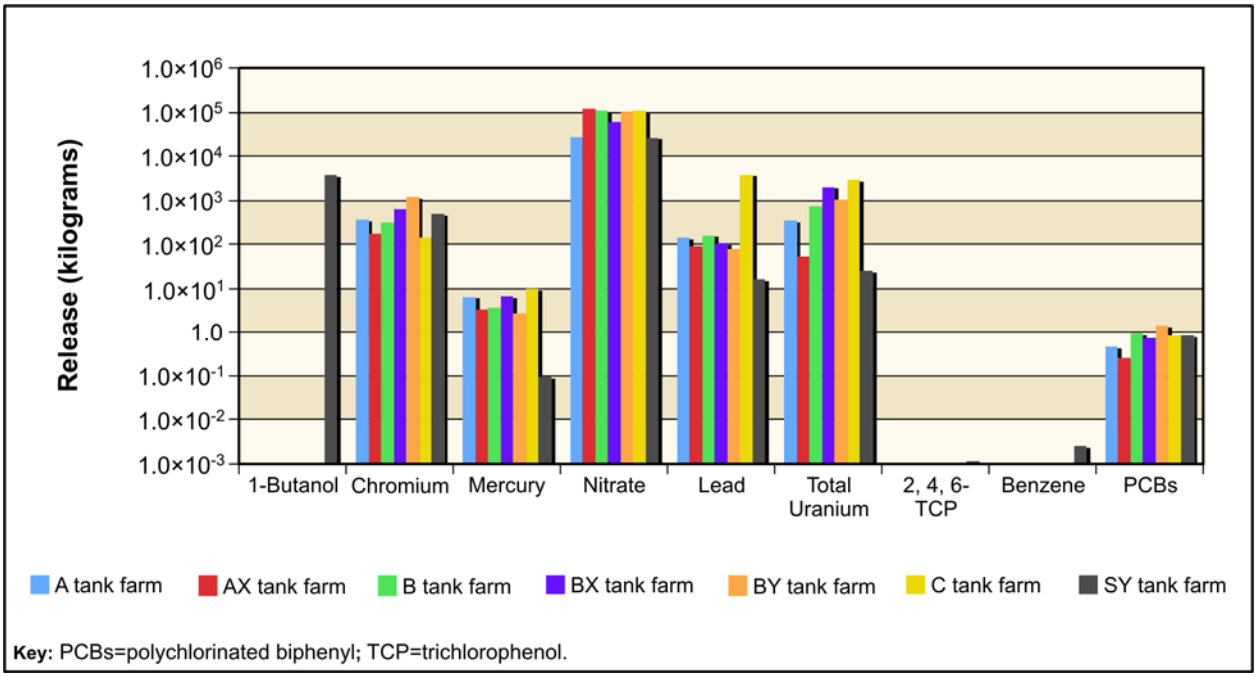


Figure M–21. Tank Closure Alternative 2A Chemical Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

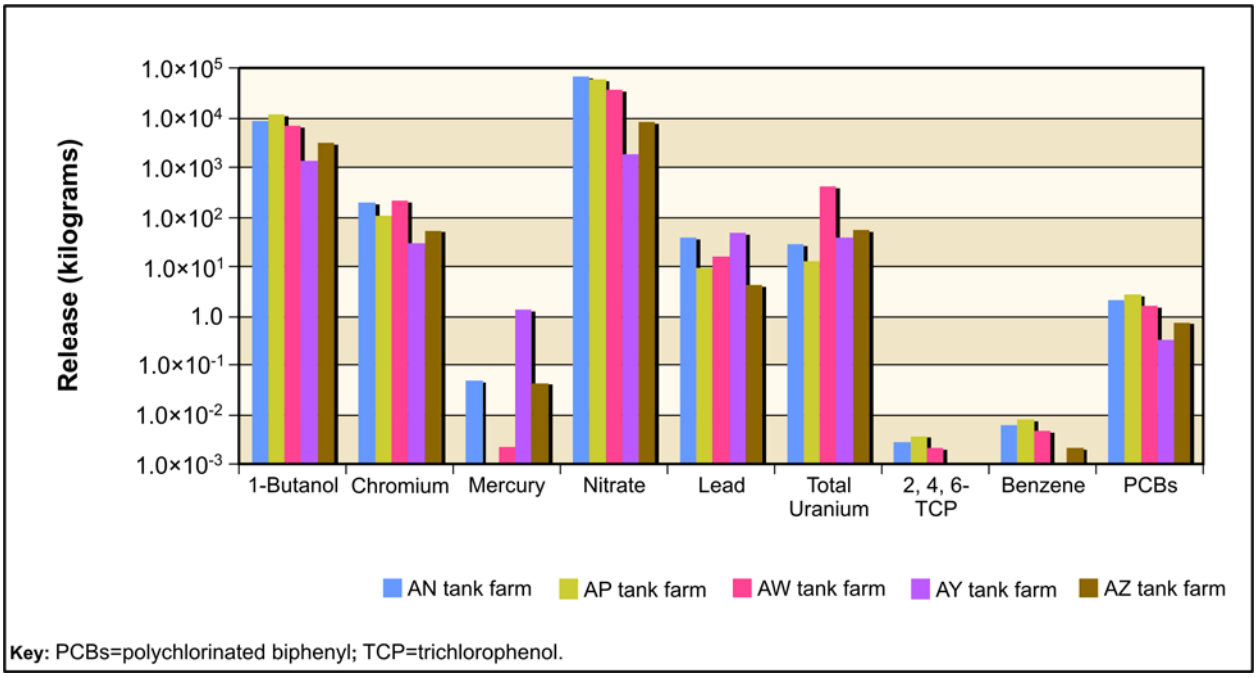


Figure M–22. Tank Closure Alternative 2A Chemical Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, and AZ

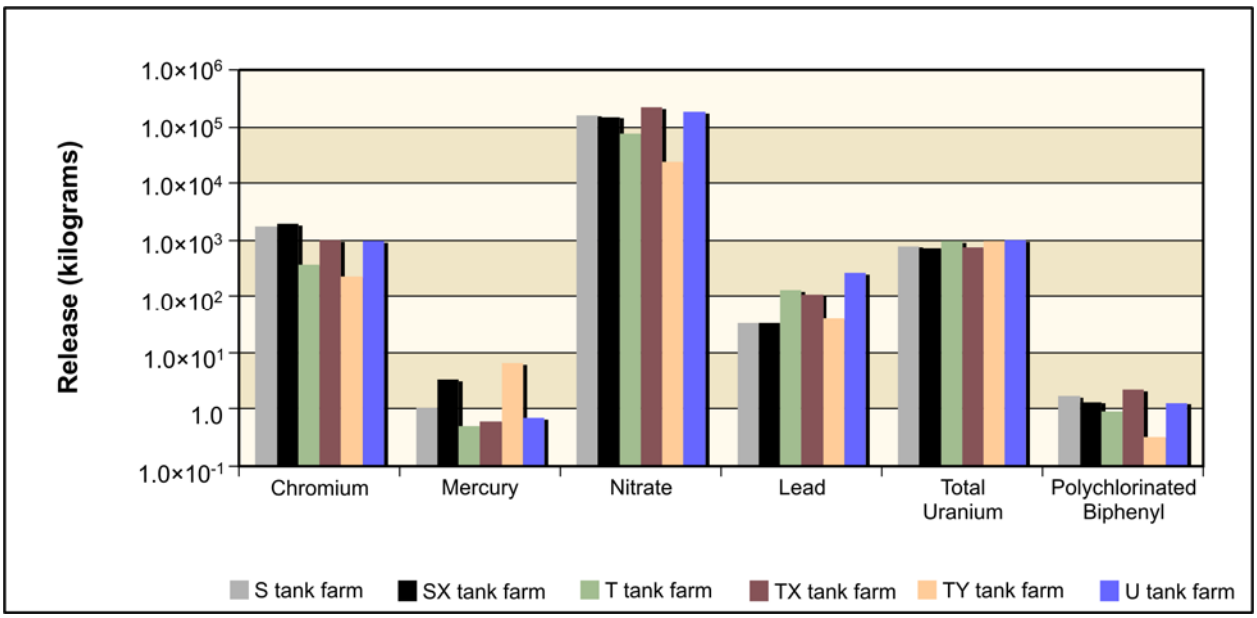


Figure M–23. Tank Closure Alternative 2A Chemical Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar to those of Tank Closure Alternative 2A, except that residual material in tanks would be stabilized in place. Soil would be removed down to 4.6 meters (15 feet) for the BX and SX tank farms and replaced with clean soil from onsite sources. Potential releases to the vadose zone under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C are indicated in Figures M–24 through M–29.

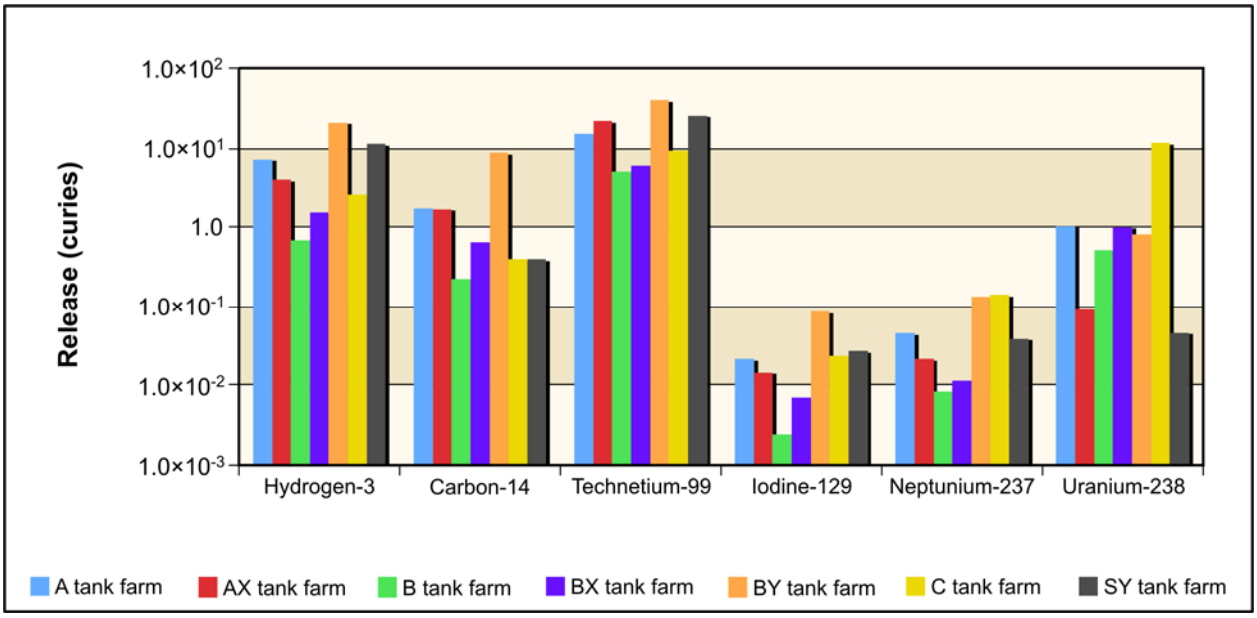


Figure M–24. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radiological Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

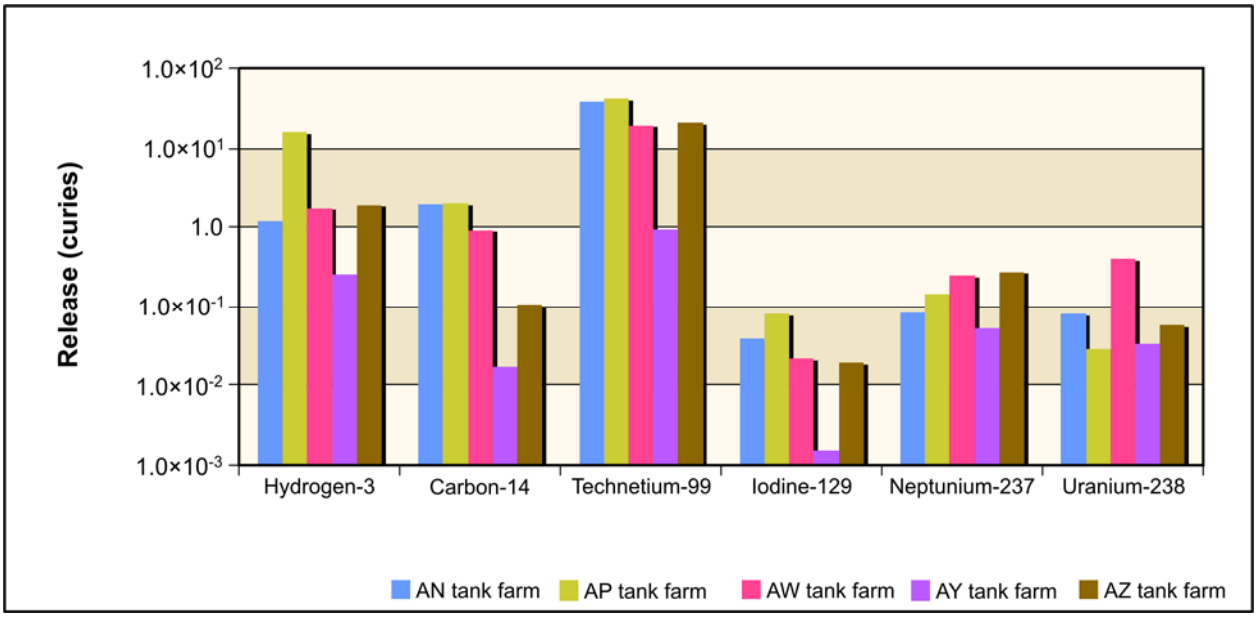


Figure M–25. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radiological Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

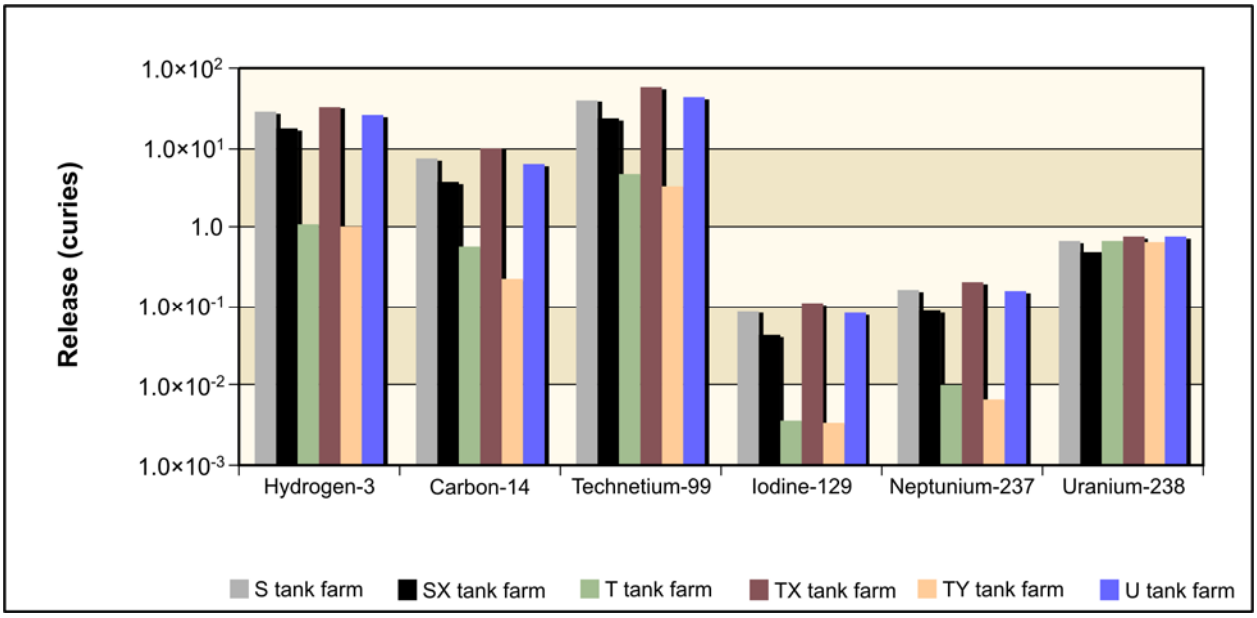


Figure M–26. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radiological Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

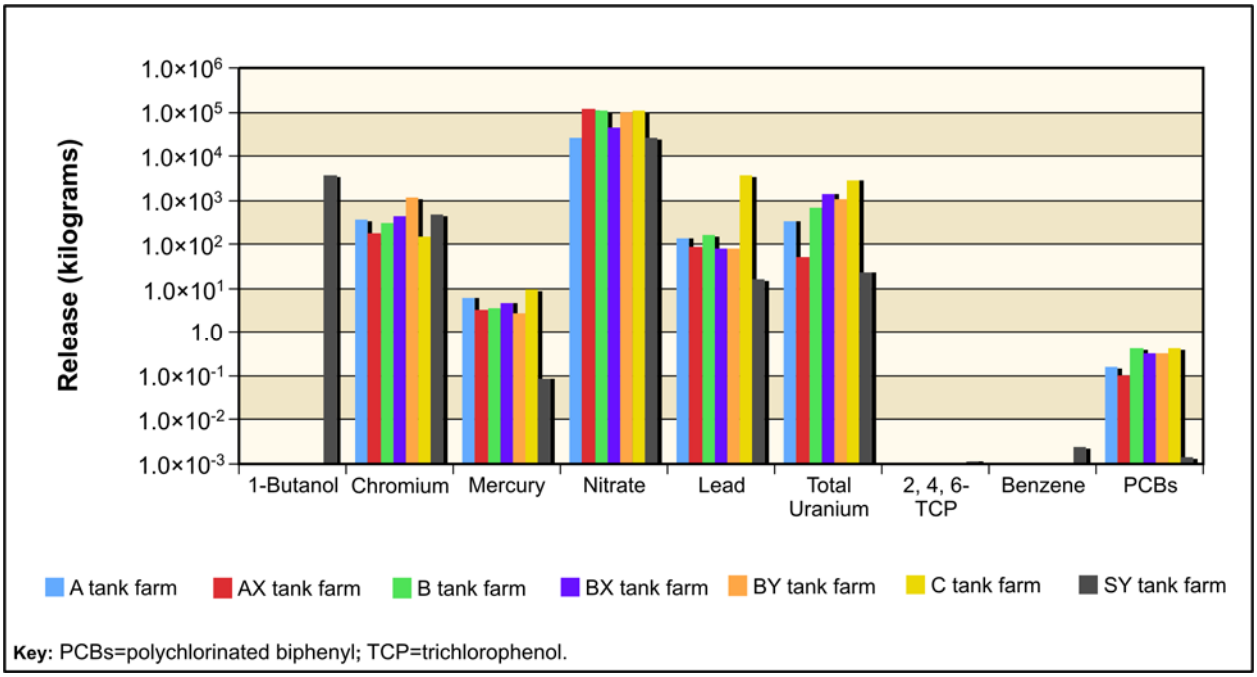


Figure M–27. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

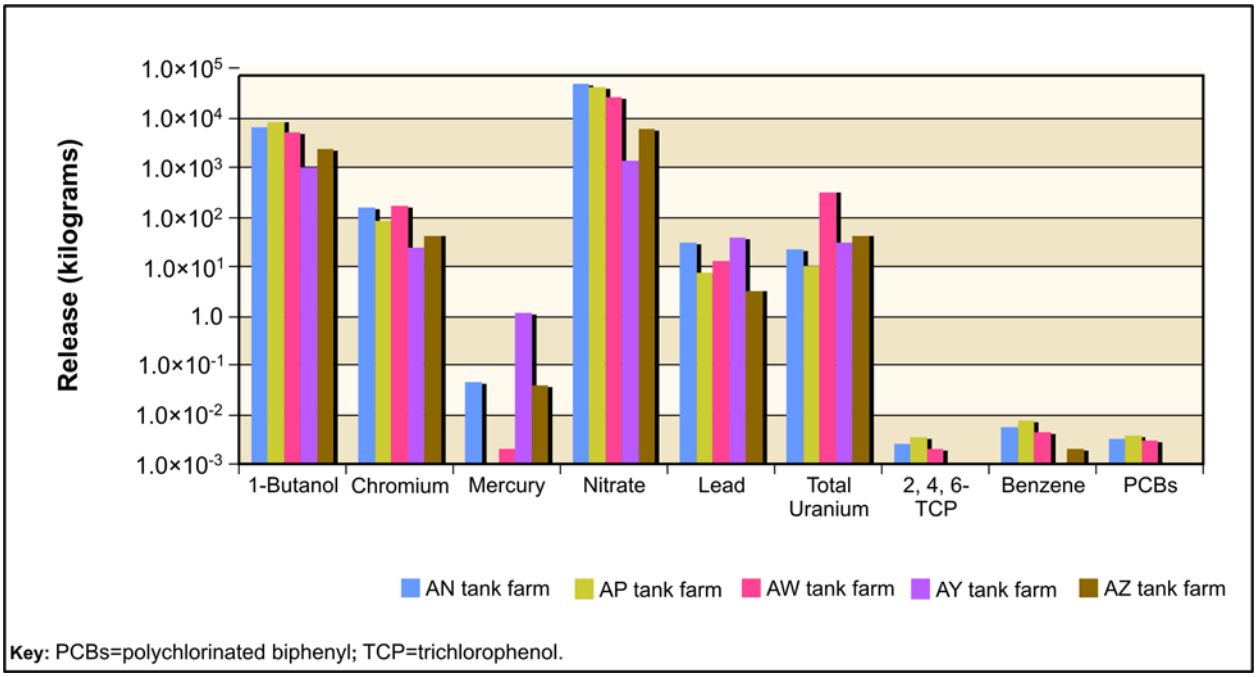


Figure M–28. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

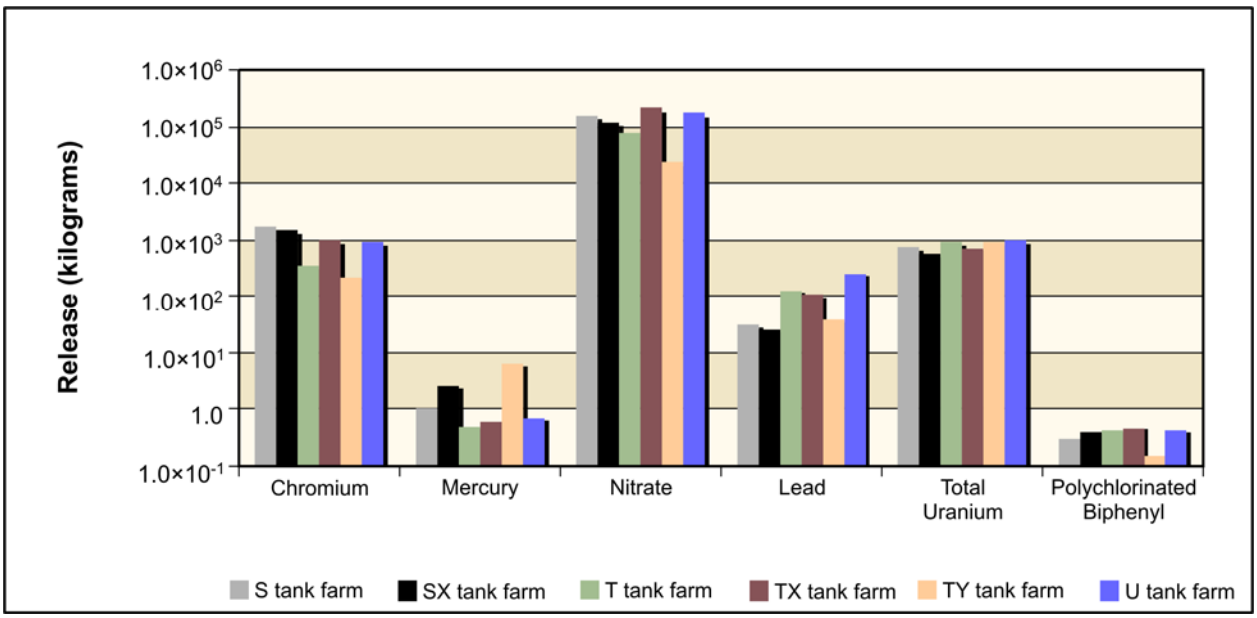


Figure M–29. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

Under Tank Closure Alternative 4, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval. Except for the BX and SX tank farms, residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. The BX and SX tank farms would be closed to a clean state by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. Potential releases to the vadose zone under Tank Closure Alternative 4 are indicated in Figures M–30 through M–35.

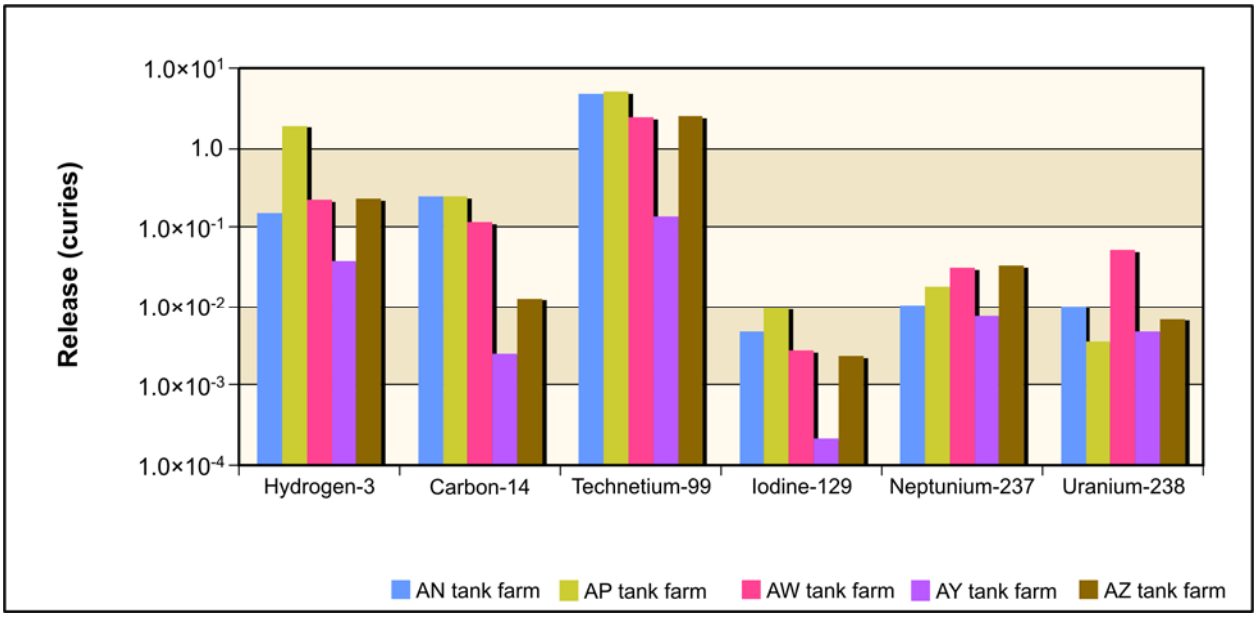


Figure M–30. Tank Closure Alternative 4 Radiological Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

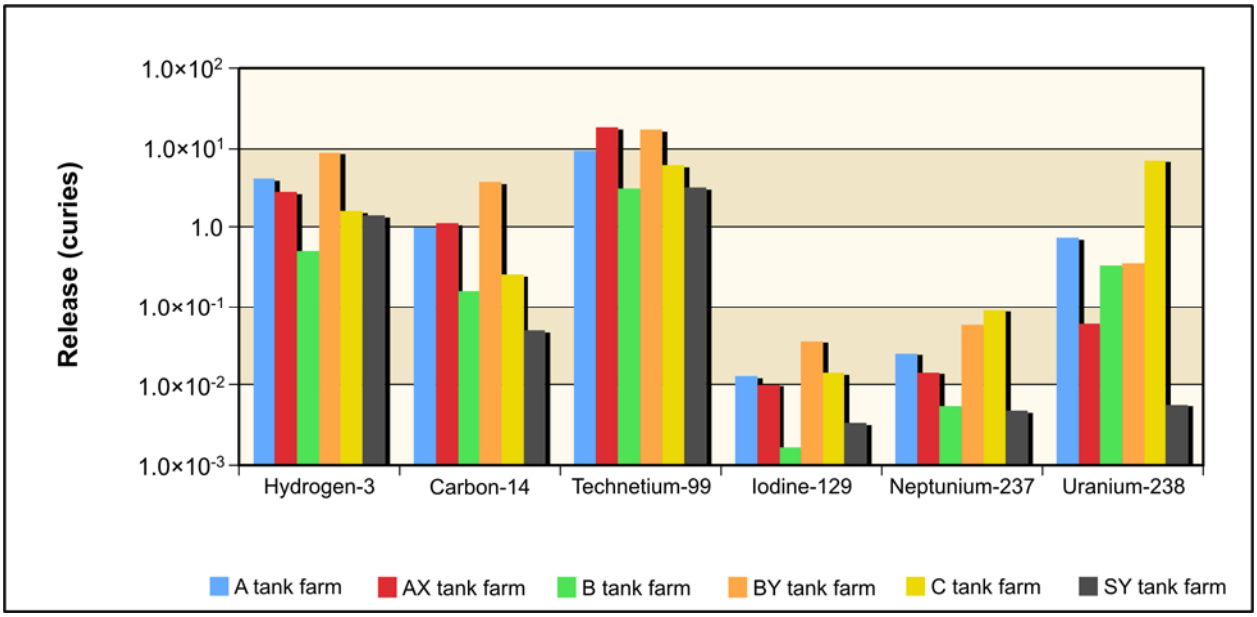


Figure M–31. Tank Closure Alternative 4 Radiological Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C and SY

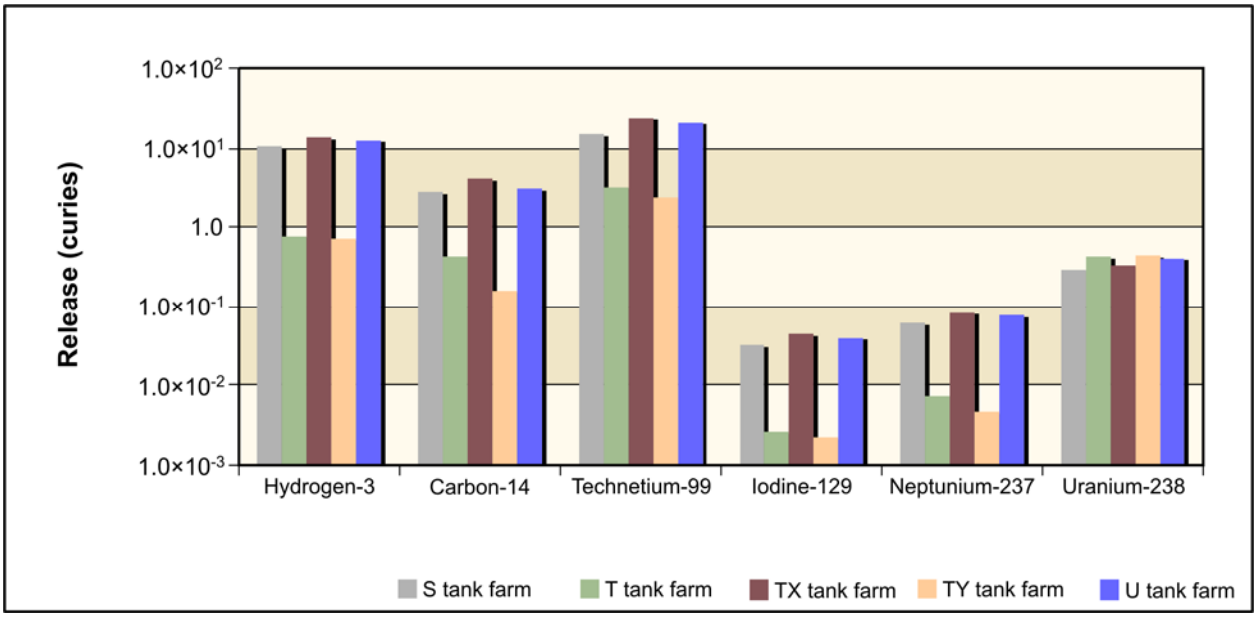


Figure M–32. Tank Closure Alternative 4 Radiological Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

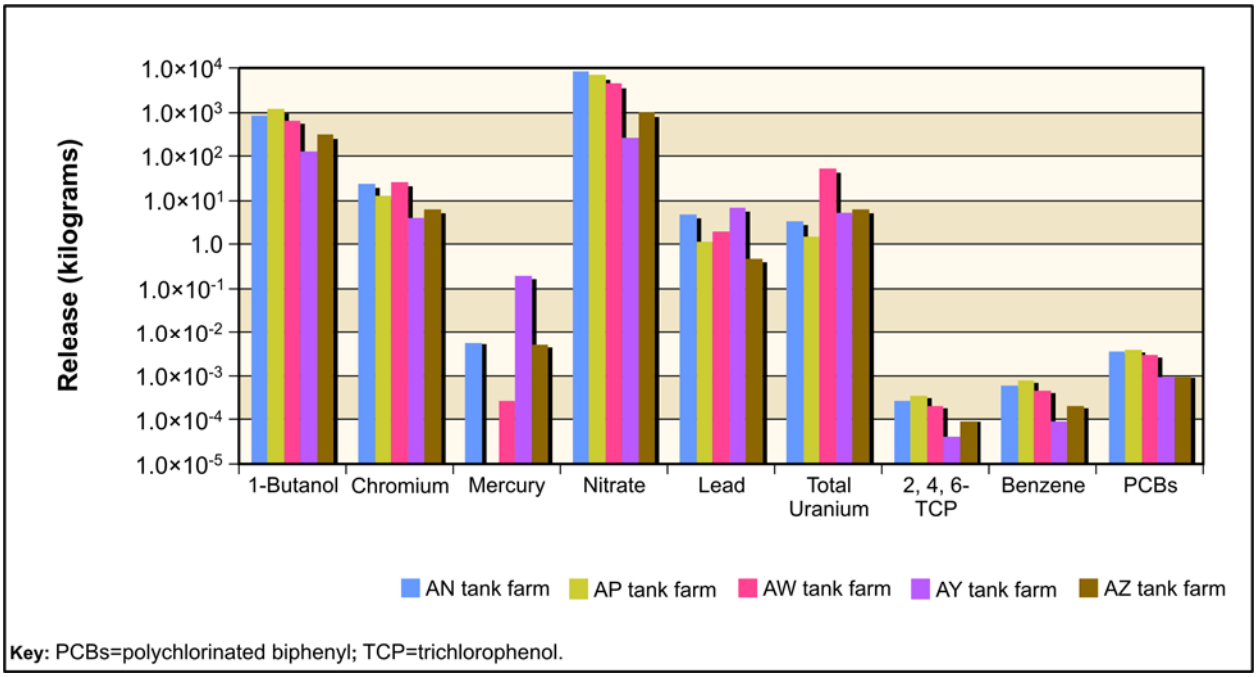


Figure M–33. Tank Closure Alternative 4 Chemical Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

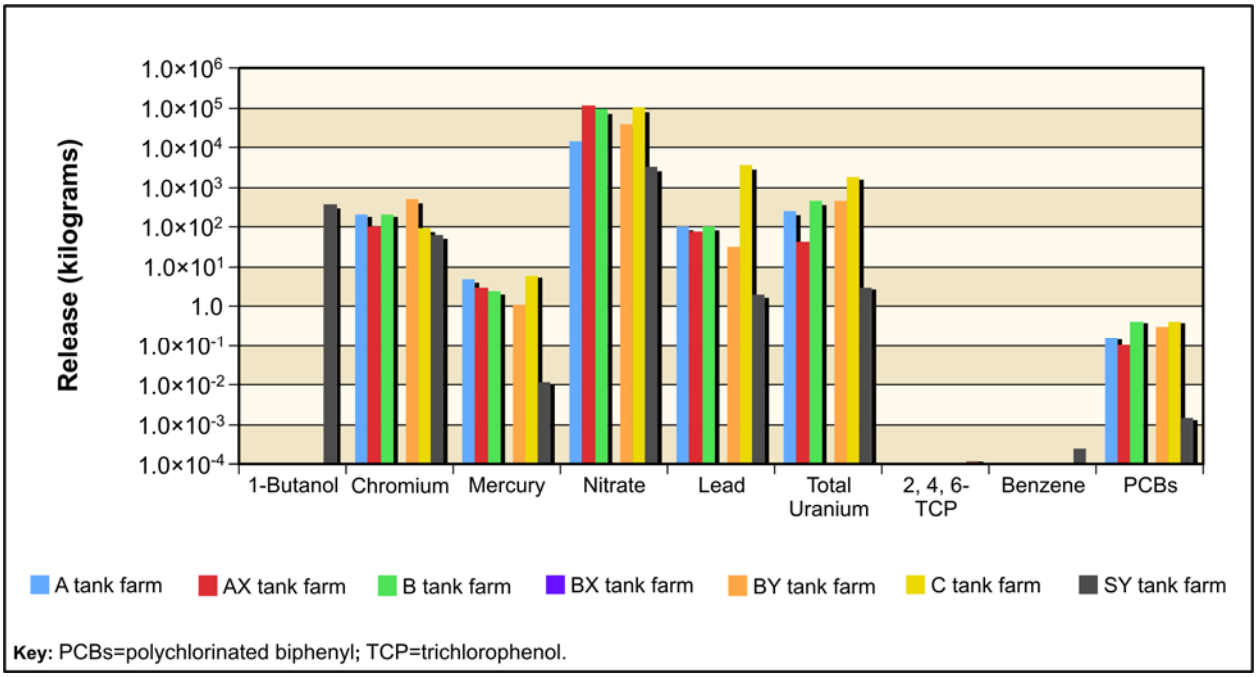


Figure M–34. Tank Closure Alternative 4 Chemical Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

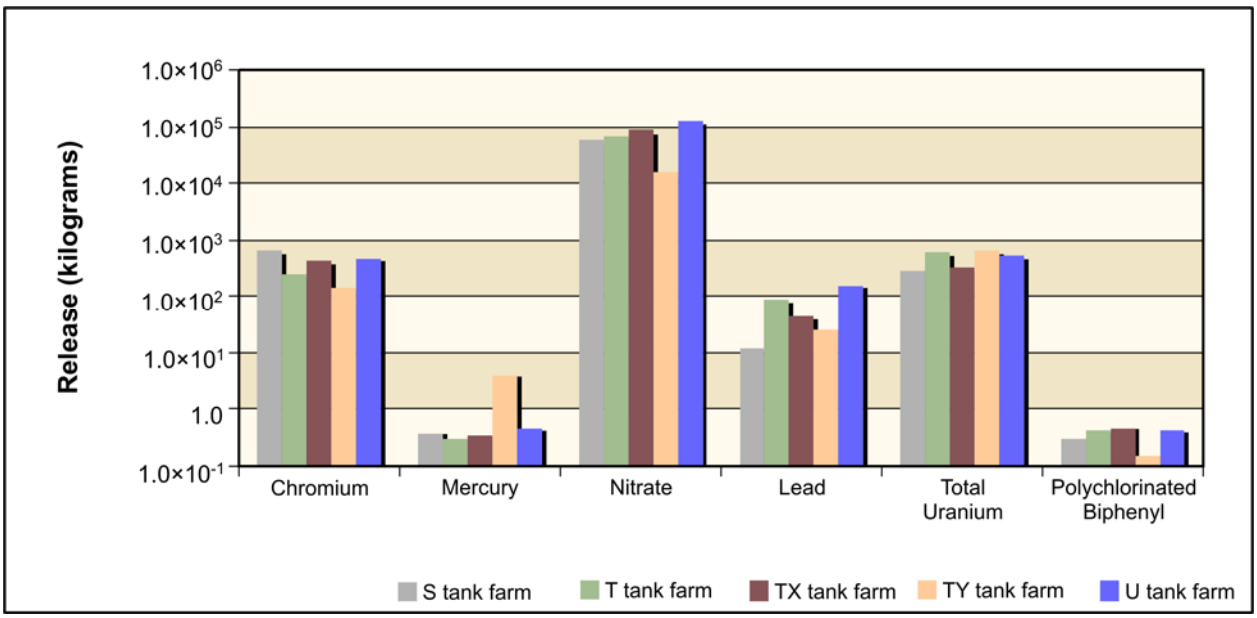


Figure M–35. Tank Closure Alternative 4 Chemical Releases to Vadose Zone from Other Sources in Tank Farms S, T, TX, TY, and U

Under Tank Closure Alternative 5, tank waste would be retrieved to a volume corresponding to 90 percent retrieval, residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with a Hanford barrier. Potential releases to the vadose zone under Tank Closure Alternative 5 are indicated in Figures M–36 through M–41.

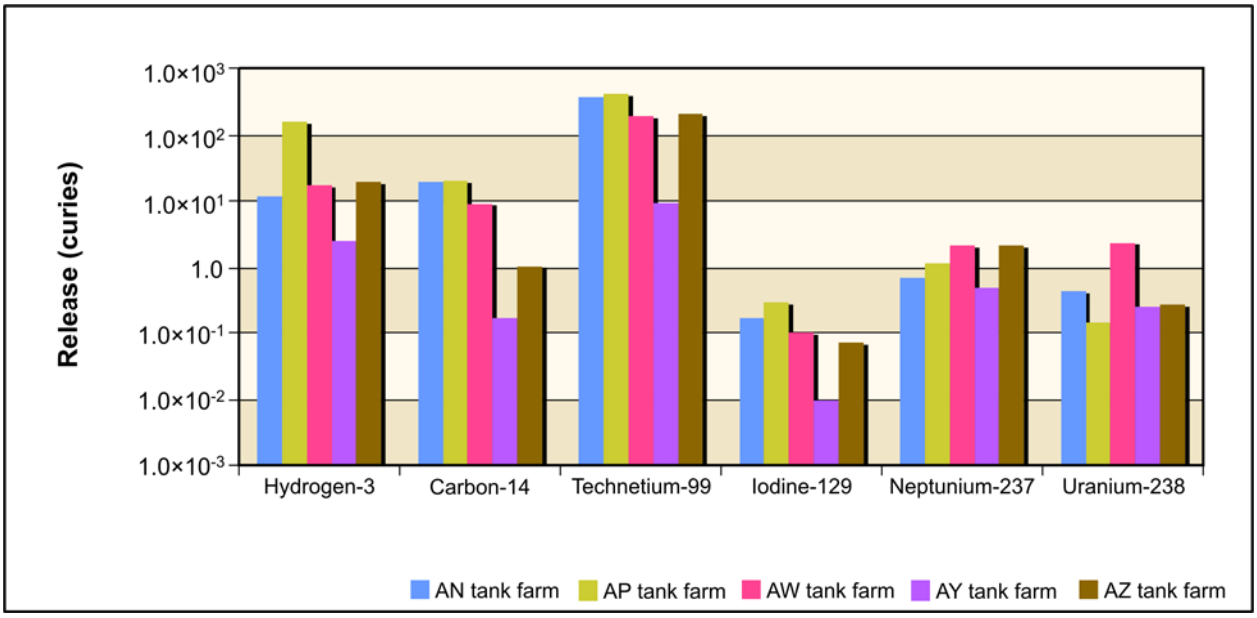


Figure M–36. Tank Closure Alternative 5 Radiological Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

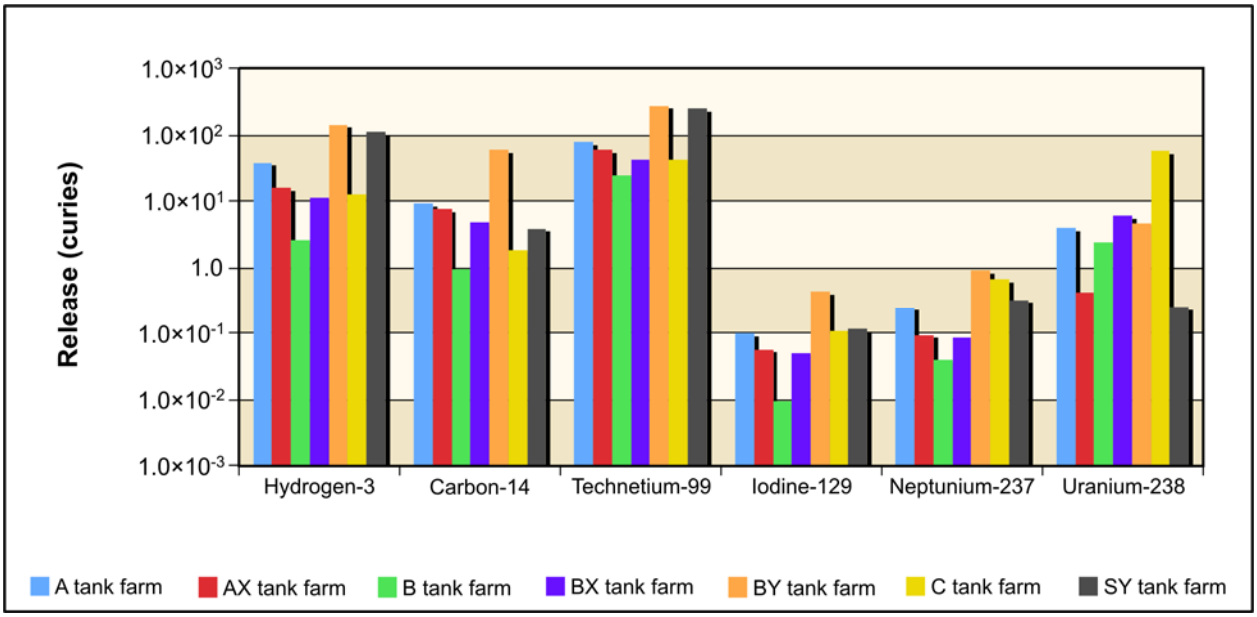


Figure M–37. Tank Closure Alternative 5 Radiological Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

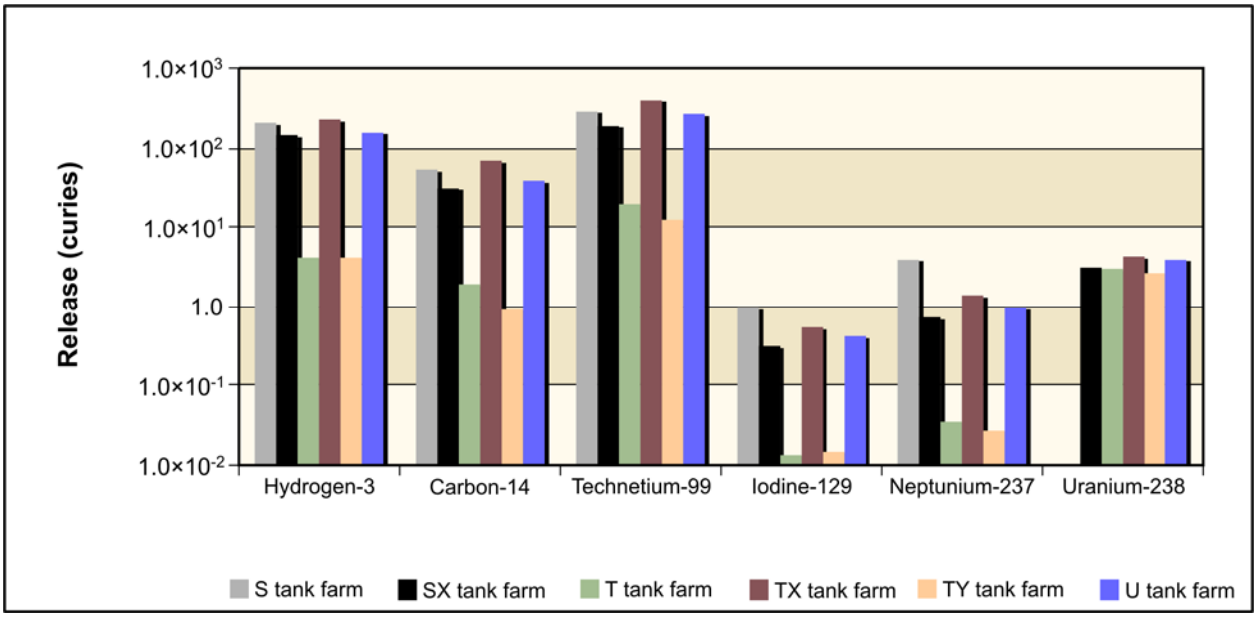


Figure M–38. Tank Closure Alternative 5 Radiological Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

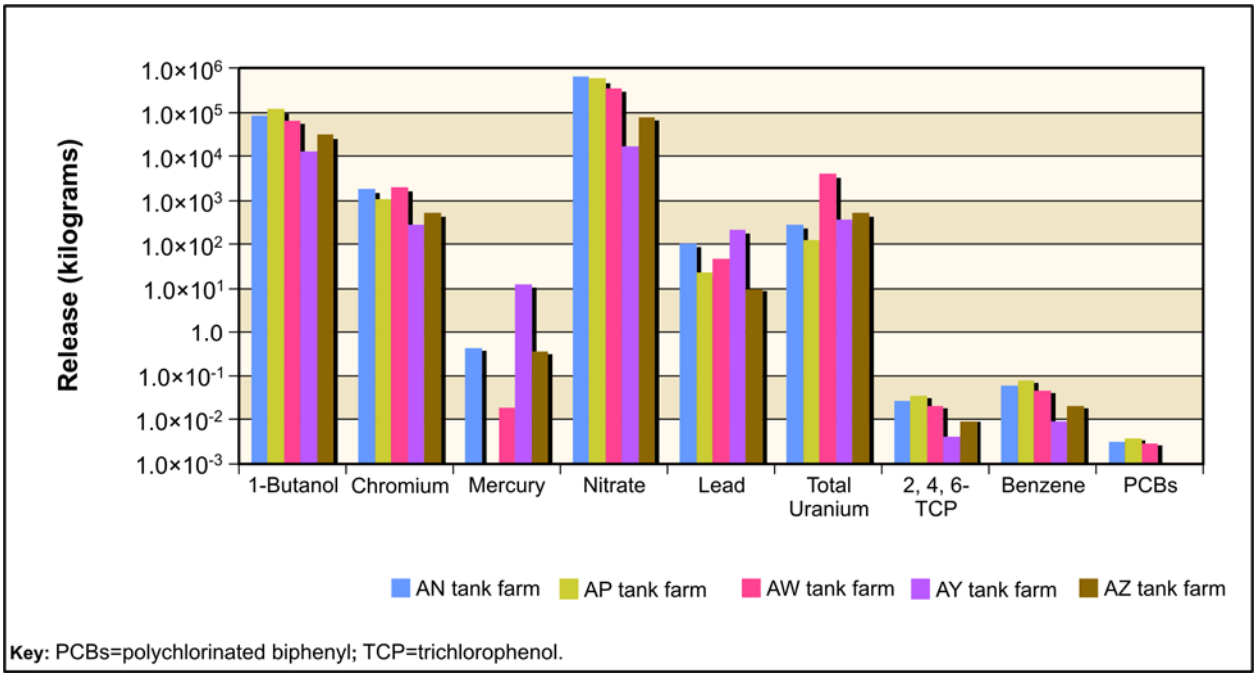


Figure M–39. Tank Closure Alternative 5 Chemical Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

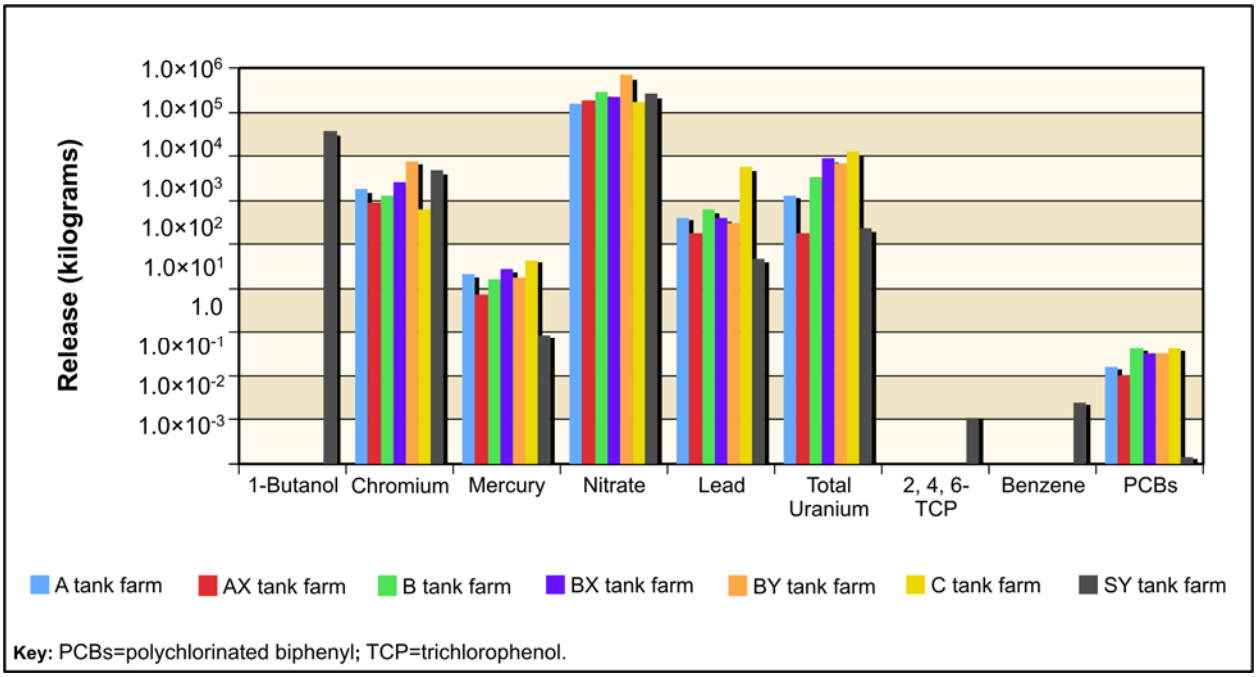


Figure M–40. Tank Closure Alternative 5 Chemical Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

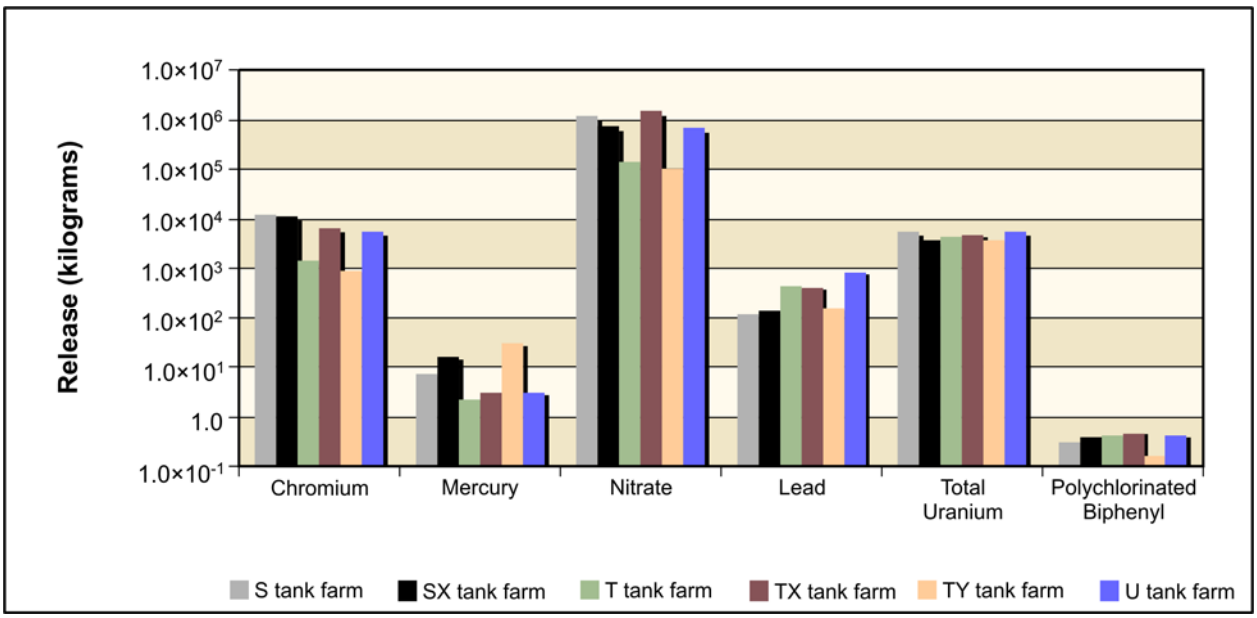


Figure M–41. Tank Closure Alternative 5 Chemical Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

M.4.2 FFTF Decommissioning Alternatives

M.4.2.1 FFTF Decommissioning Alternative 1: No Action

Under FFTF Decommissioning Alternative 1, only those actions consistent with previous DOE National Environmental Policy Act actions would be completed. Final decommissioning of FFTF would not occur. For purpose of analysis, the remaining waste would be available for release to the environment

after an institutional control period of 100 years. Potential releases to the vadose zone under FFTF Decommissioning Alternative 1 are indicated in Figures M–42 and M–43.

M.4.2.2 FFTF Decommissioning Alternative 2: Entombment

Under FFTF Decommissioning Alternative 2, all aboveground structures and minimal below-grade structures, equipment, and materials would be removed. An RCRA-compliant barrier would be constructed over the RCB and any other remaining below-grade structures (including the reactor vessel). Potential releases to the vadose zone under FFTF Decommissioning Alternative 2 are indicated in Figure M–44.

M.4.2.3 FFTF Decommissioning Alternative 3: Removal

Under FFTF Decommissioning Alternative 3, all aboveground structures and contaminated below-grade structures, equipment, and materials would be removed. Potential releases to the vadose zone under FFTF Decommissioning Alternative 3 are indicated in Figure M–45.

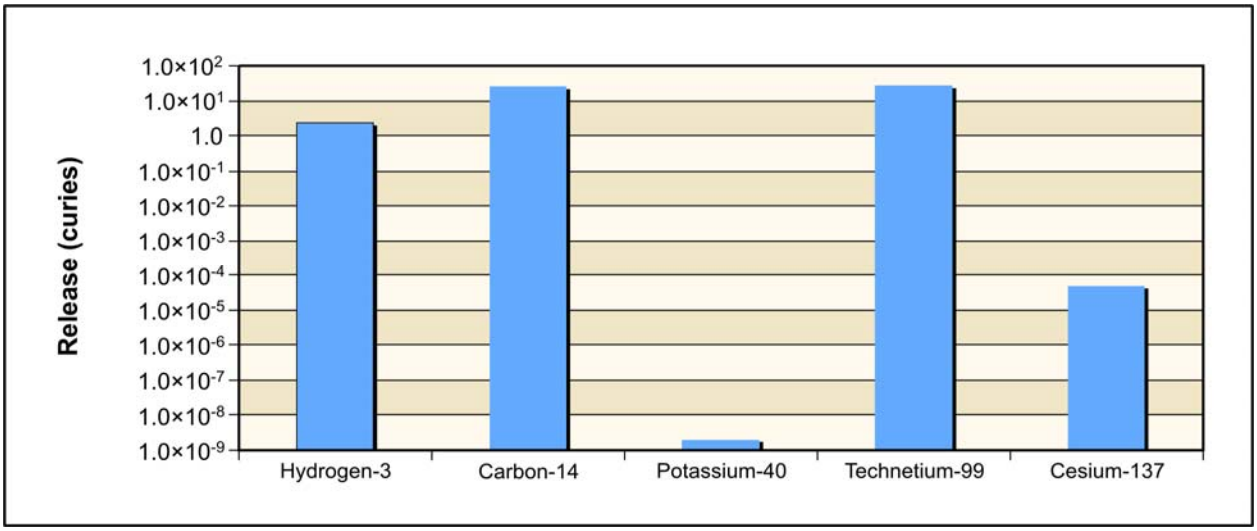


Figure M–42. FFTF Decommissioning Alternative 1 Radiological Releases to Vadose Zone

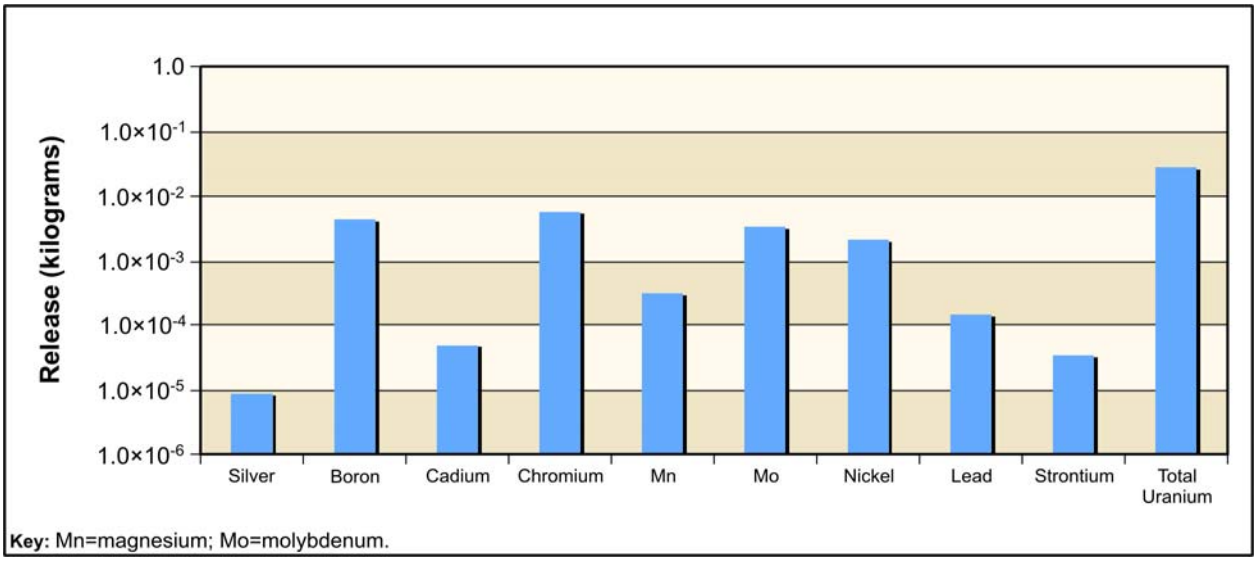


Figure M–43. FFTF Decommissioning Alternative 1 Chemical Releases to Vadose Zone

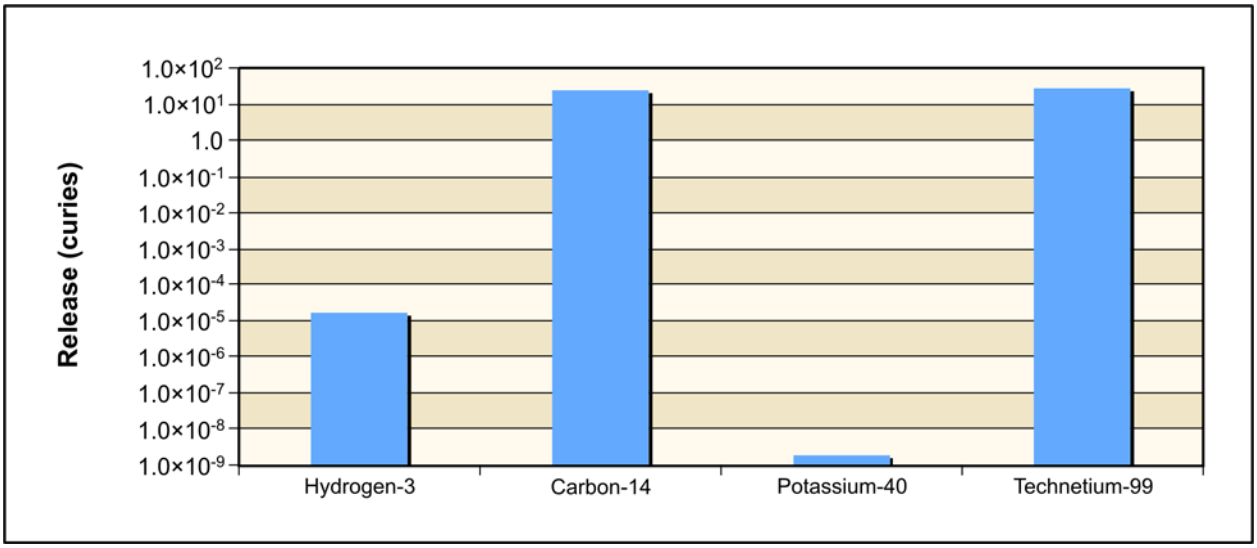


Figure M–44. FFTF Decommissioning Alternative 2 Radiological Releases to Vadose Zone

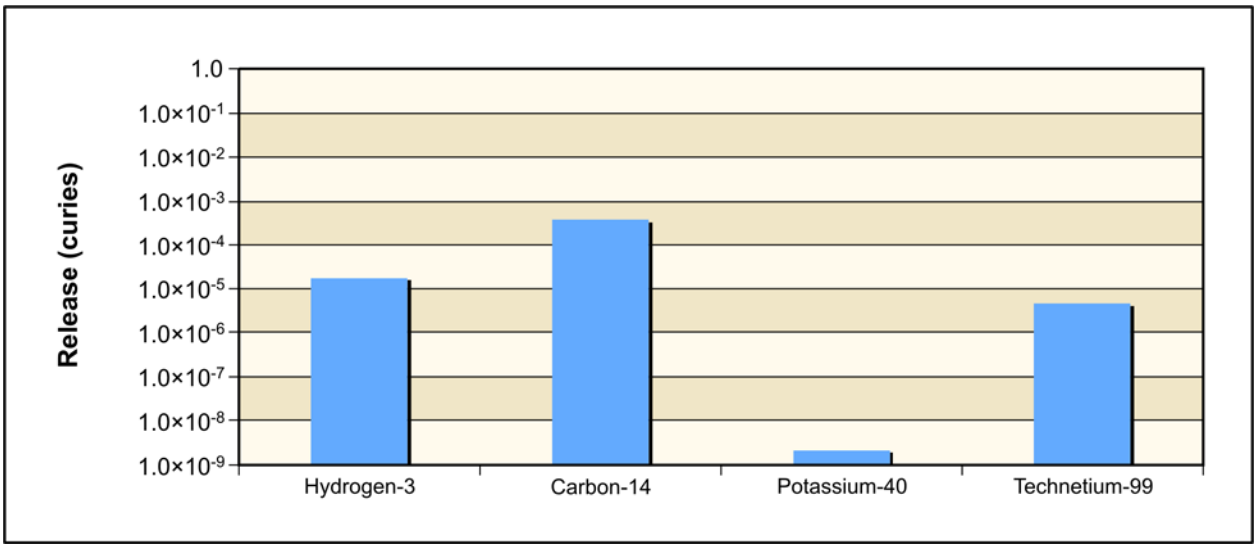


Figure M–45. FFTF Decommissioning Alternative 3 Radiological Releases to Vadose Zone

M.4.3 Waste Management Alternatives

M.4.3.1 Waste Management Alternative 1

Under Waste Management Alternative 1, only the waste currently generated onsite at Hanford from non-CERCLA actions would continue to be disposed of in the LLBG 218-W-5, trenches 31 and 34. Although short-term impacts do not address impacts associated with closure activities for this site, for purposes of analysis for long-term impacts it is assumed that these trenches would be closed using an RCRA-compliant barrier consistent with the closure plans for these burial grounds. As a result, the non-CERCLA waste disposed of in these trenches from 2008 to 2035 would become available for release to the environment. Potential releases to the vadose zone under Waste Management Alternative 1 are indicated in Figures M–46 and M–47.

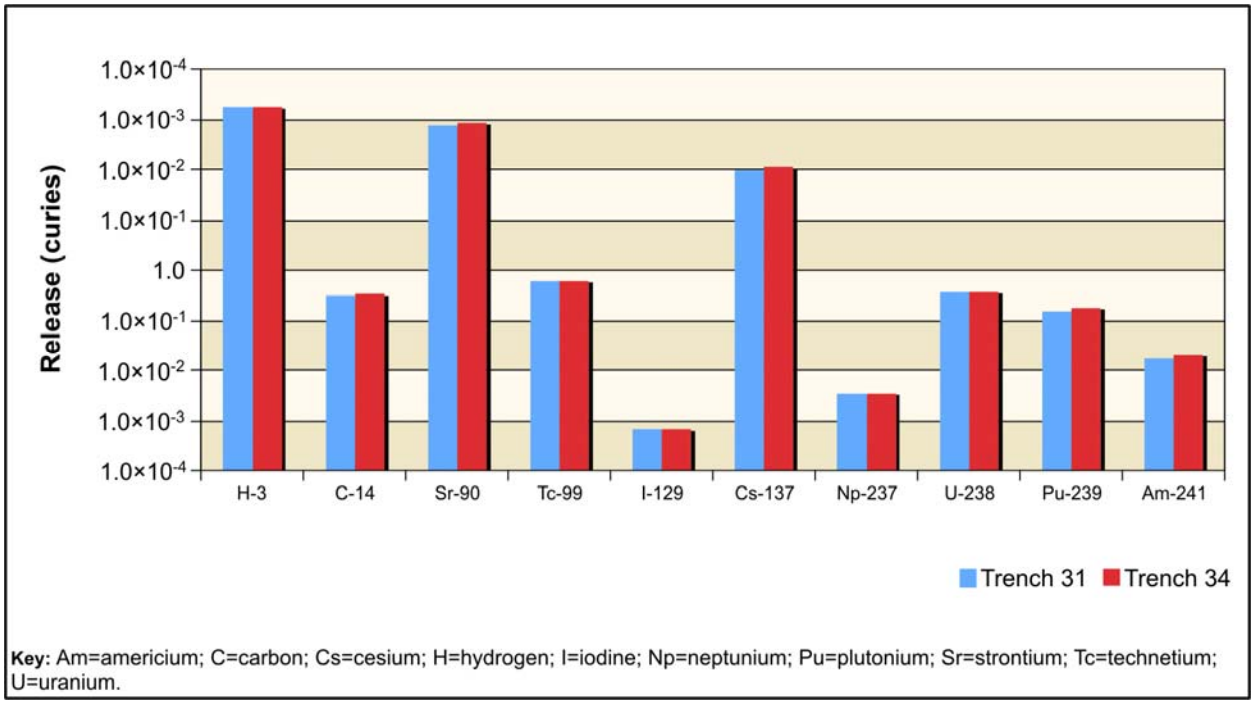


Figure M–46. Waste Management Alternative 1 Radiological Releases to Vadose Zone

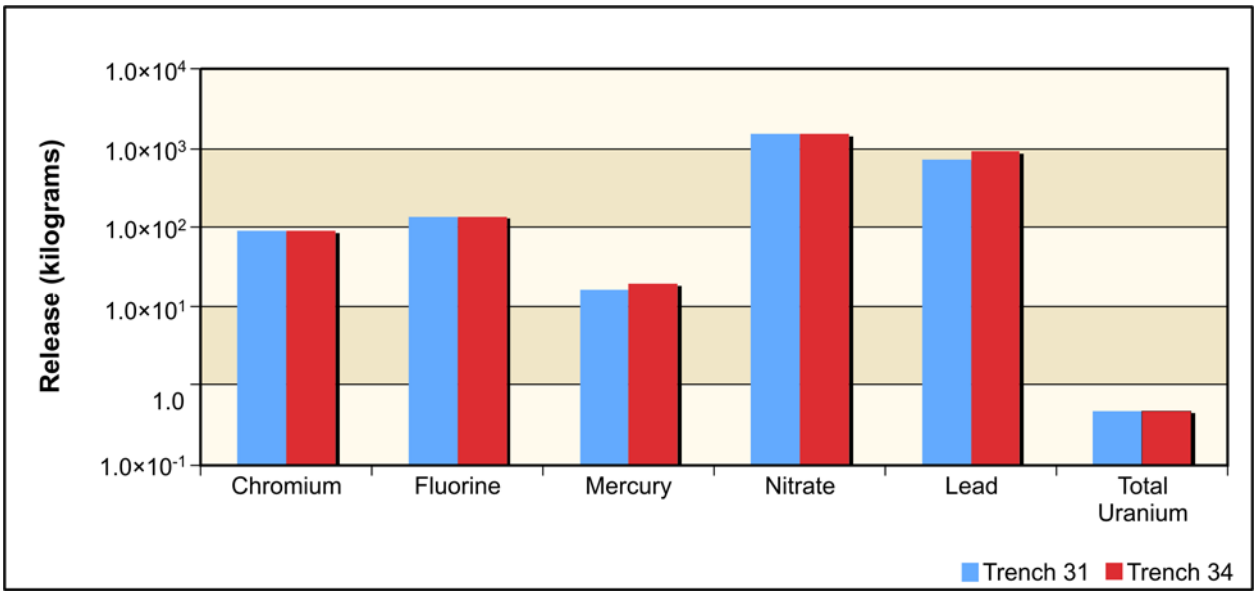


Figure M–47. Waste Management Alternative 1 Chemical Releases to Vadose Zone

M.4.3.2 Waste Management Alternative 2

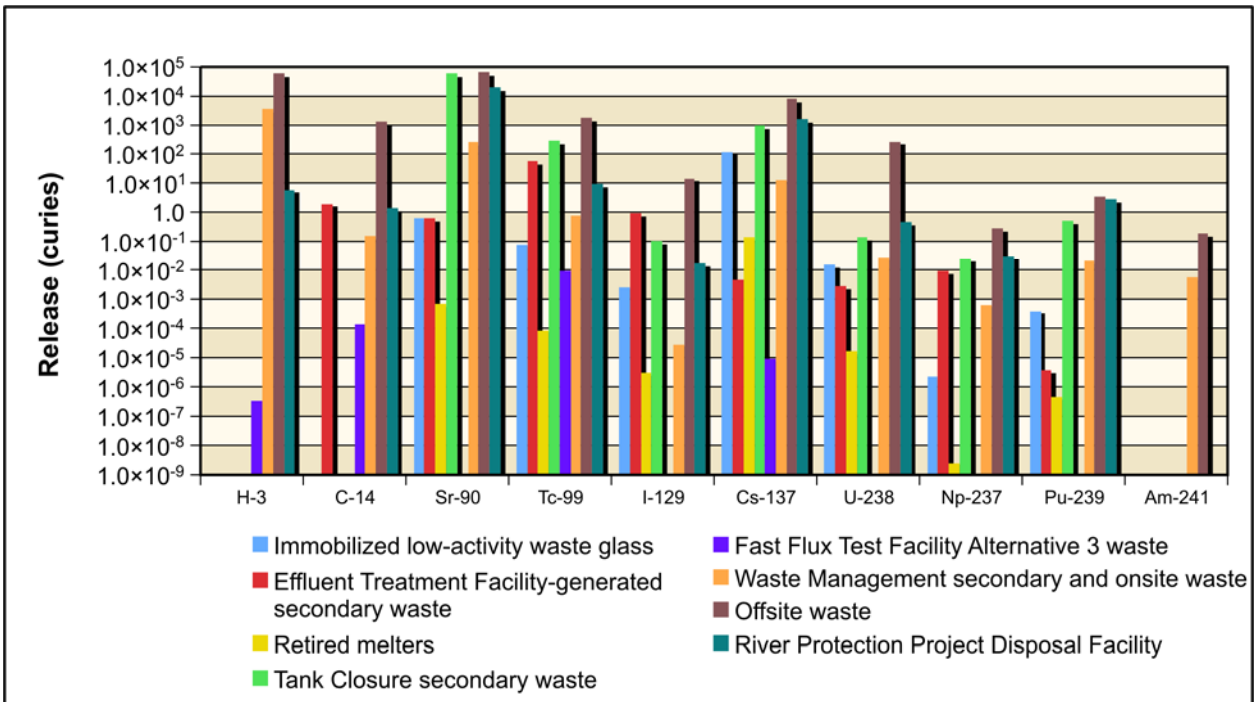
Under Waste Management Alternative 2, waste from tank treatment operations, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites would be disposed of in IDF-East. Waste from tank farm cleanup activities would be disposed of in the RPPDF. As a result, the waste disposed of in these two facilities would become available for release to the environment. Because different waste types would result from the Tank Closure action alternatives, three disposal groups were considered to account for the different IDF-East sizes and operational time periods. In addition, within these three disposal groups, subgroups were identified to allow for consideration of the different waste types resulting from the Tank Closure alternatives.

M.4.3.2.1 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-A

Disposal Group 1, Subgroup 1-A, addresses the waste resulting from Tank Closure Alternative 2B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 2B. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, are indicated in Figures M–48 and M–49.



Key: Am=americium; C=carbon; Cs=cesium; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–48. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases to Vadose Zone

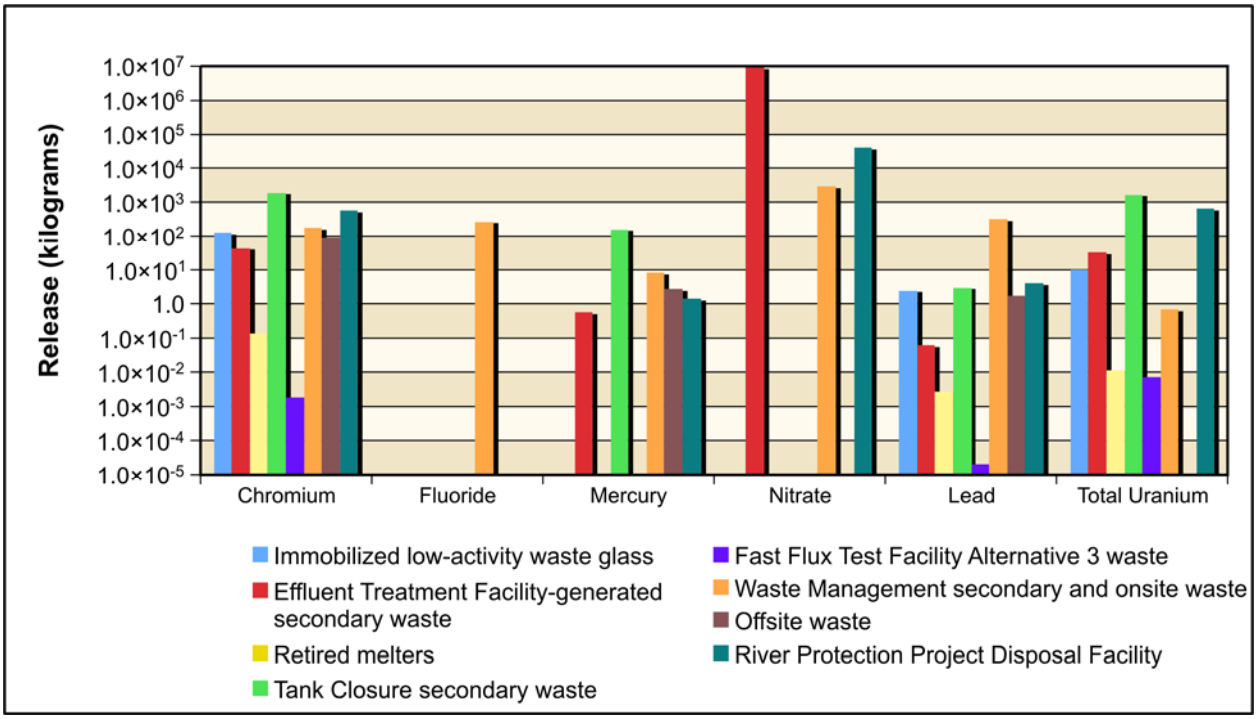


Figure M–49. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases to Vadose Zone

M.4.3.2.2 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-B

Disposal Group 1, Subgroup 1-B, addresses the waste resulting from Tank Closure Alternative 3A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3A. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, are indicated in Figures M–50 and M–51.

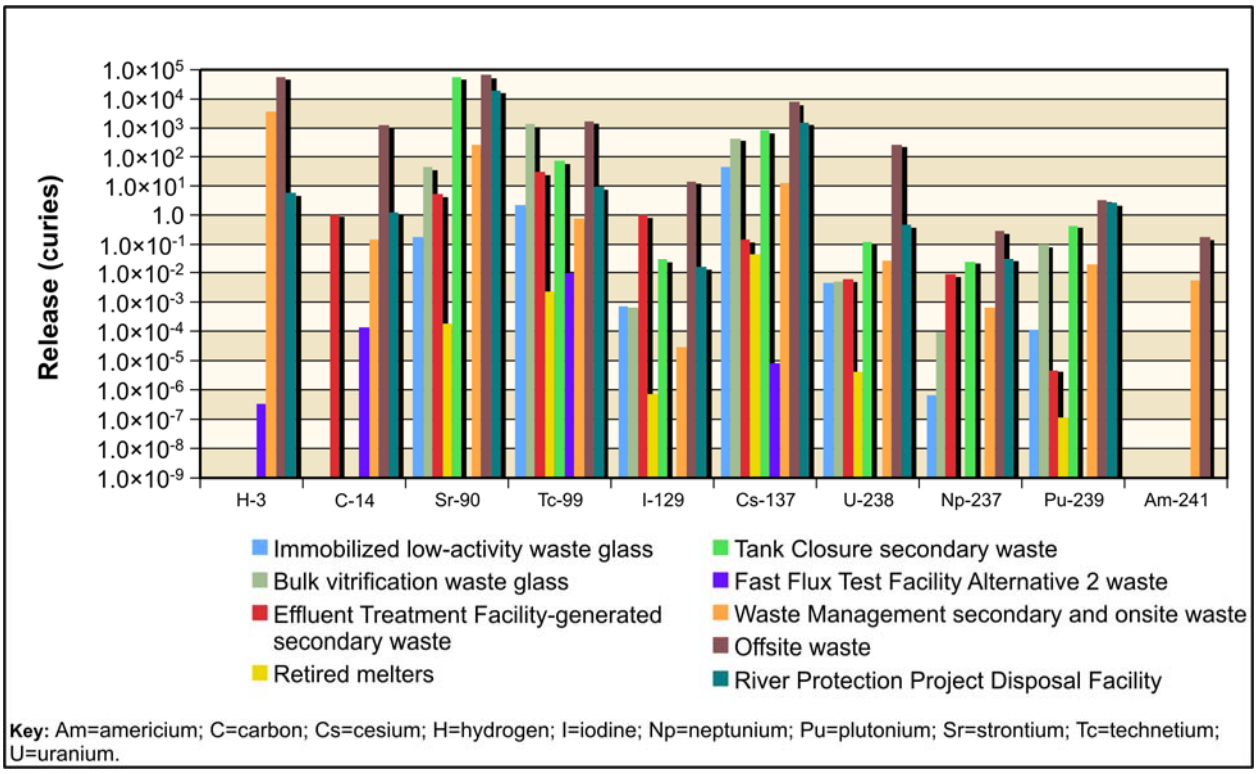


Figure M–50. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases to Vadose Zone

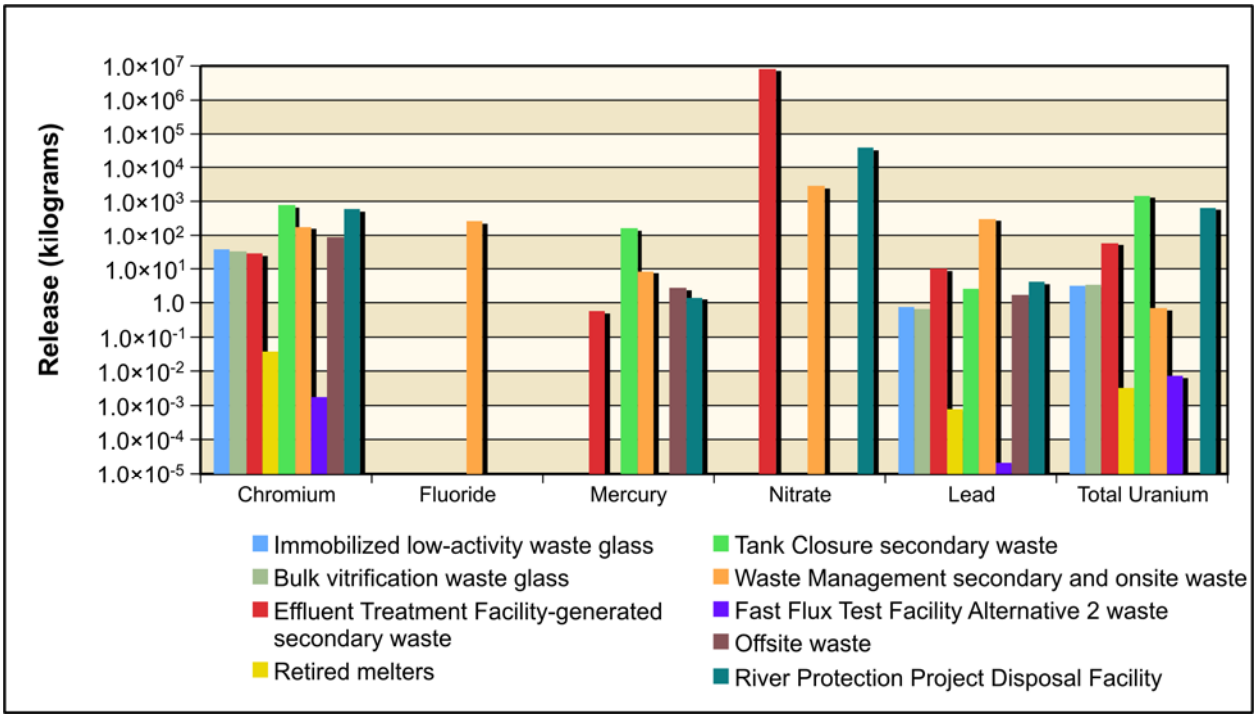


Figure M–51. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases to Vadose Zone

M.4.3.2.3 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-C

Disposal Group 1, Subgroup 1-C, addresses the waste resulting from Tank Closure Alternative 3B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Cast stone
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3B. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, are indicated in Figures M–52 and M–53.

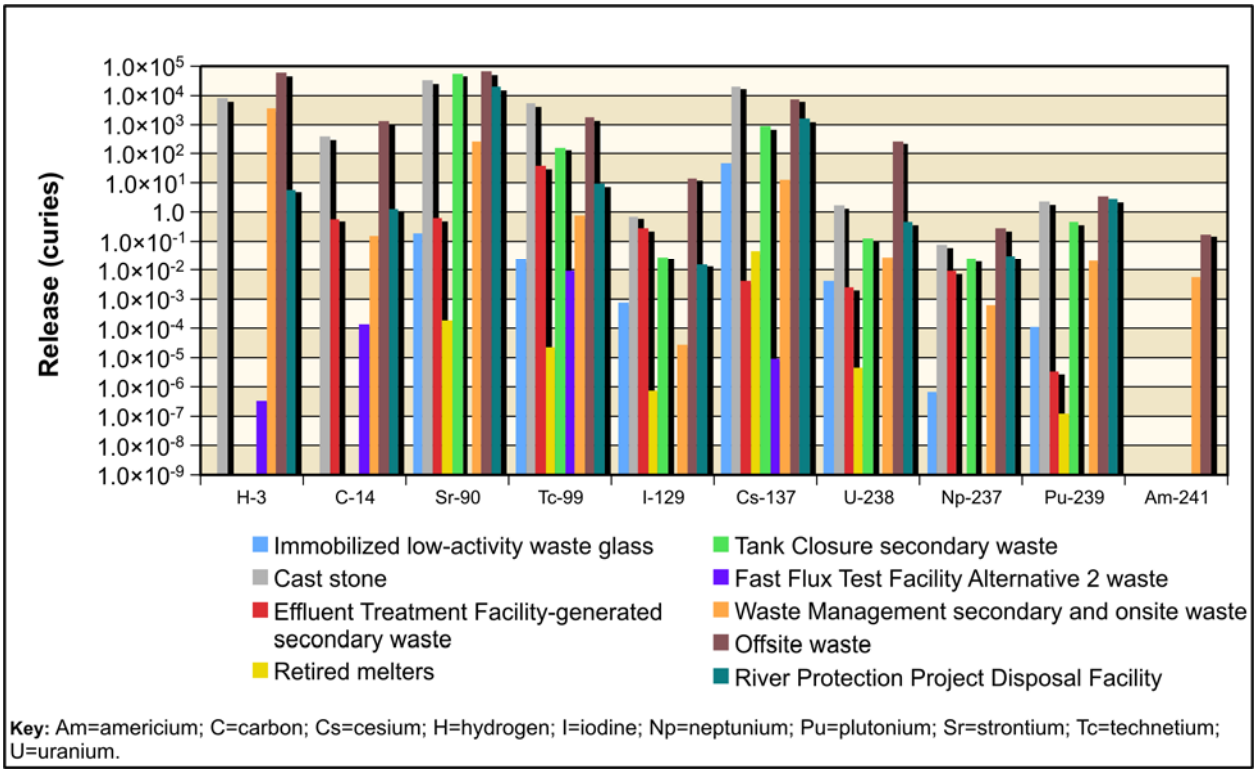


Figure M–52. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Radiological Releases to Vadose Zone

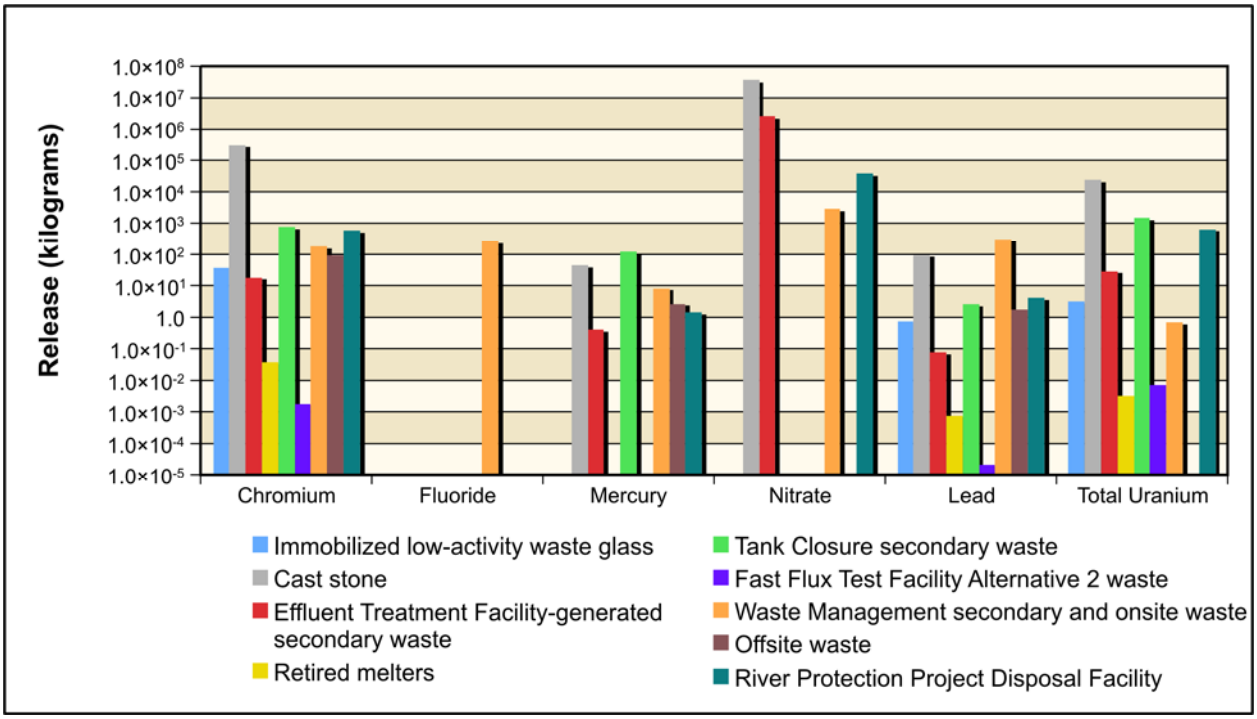


Figure M–53. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Chemical Releases to Vadose Zone

M.4.3.2.4 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-D

Disposal Group 1, Subgroup 1-D, addresses the waste resulting from Tank Closure Alternative 3C, onsite non-CERCLA sources, FFTF decommissioning, waste management and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Steam reforming waste
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3C. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, are indicated in Figures M–54 and M–55.

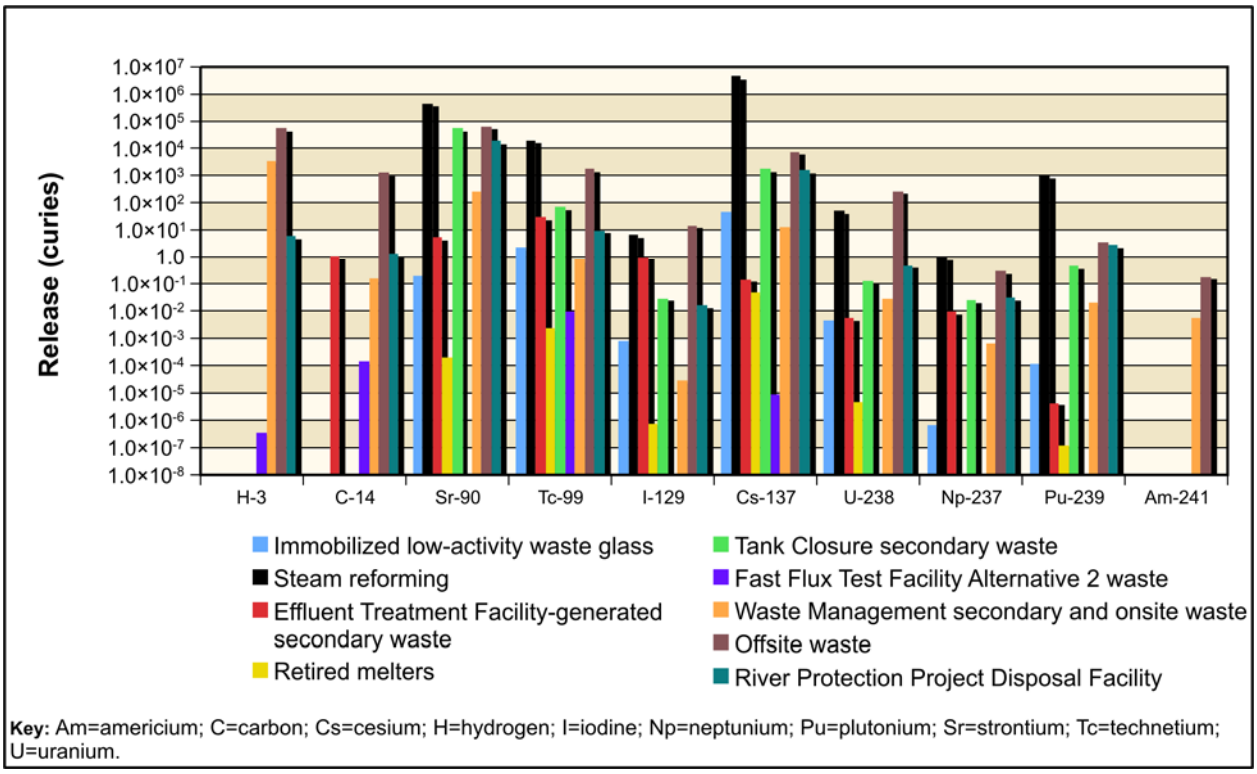


Figure M–54. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Radiological Releases to Vadose Zone

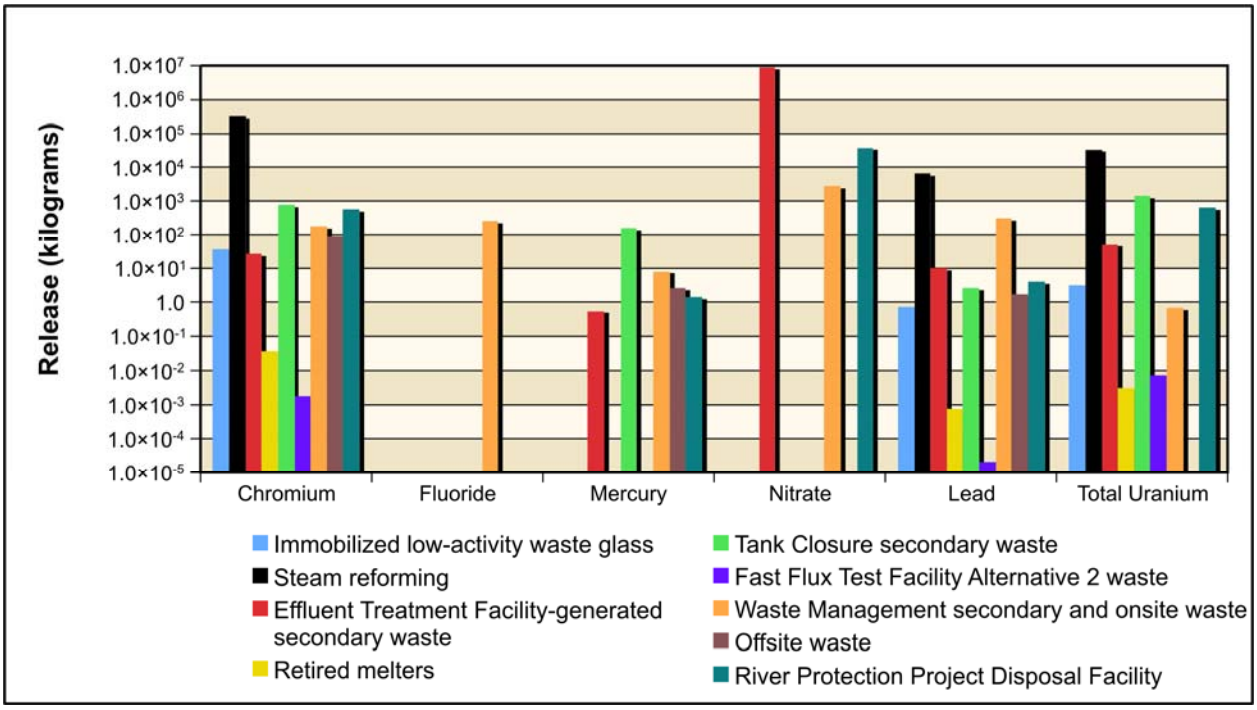


Figure M–55. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Chemical Releases to Vadose Zone

M.4.3.2.5 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-E

Disposal Group 1, Subgroup 1-E, addresses the waste resulting from Tank Closure Alternative 4, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 4. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, are indicated in Figures M–56 and M–57.

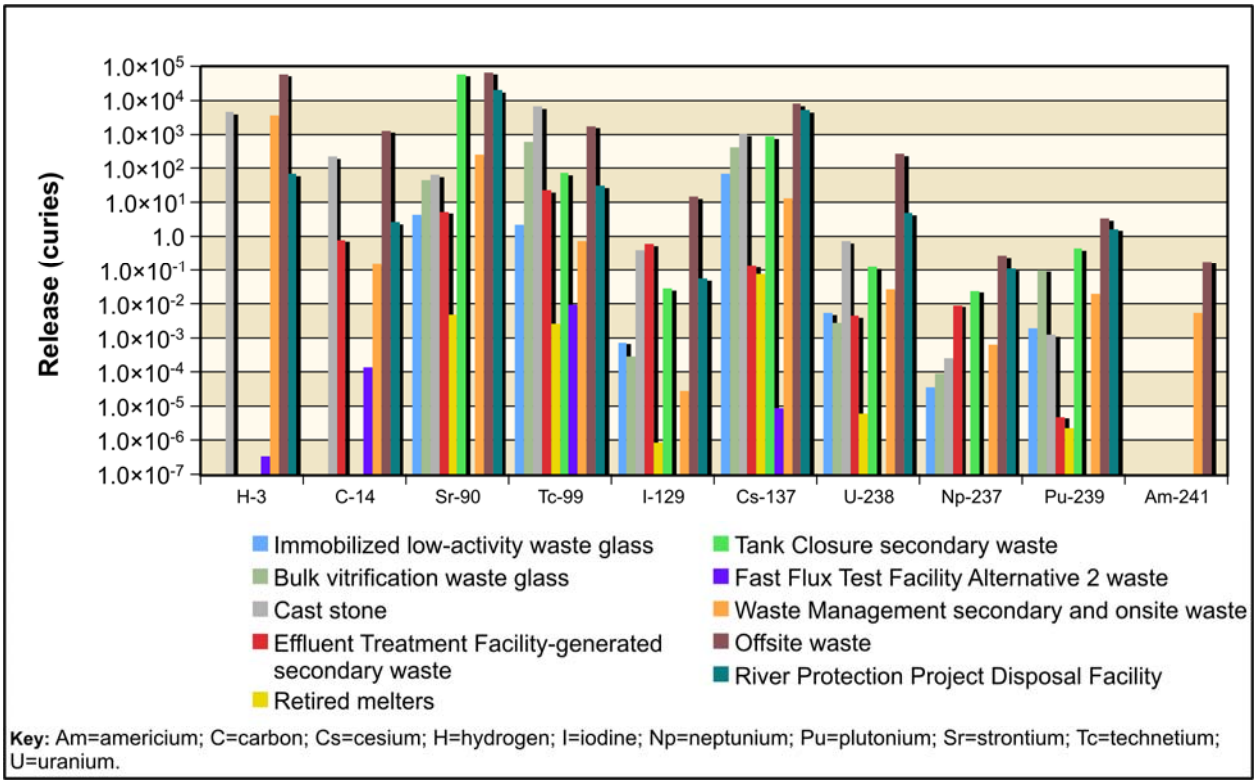


Figure M–56. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Radiological Releases to Vadose Zone

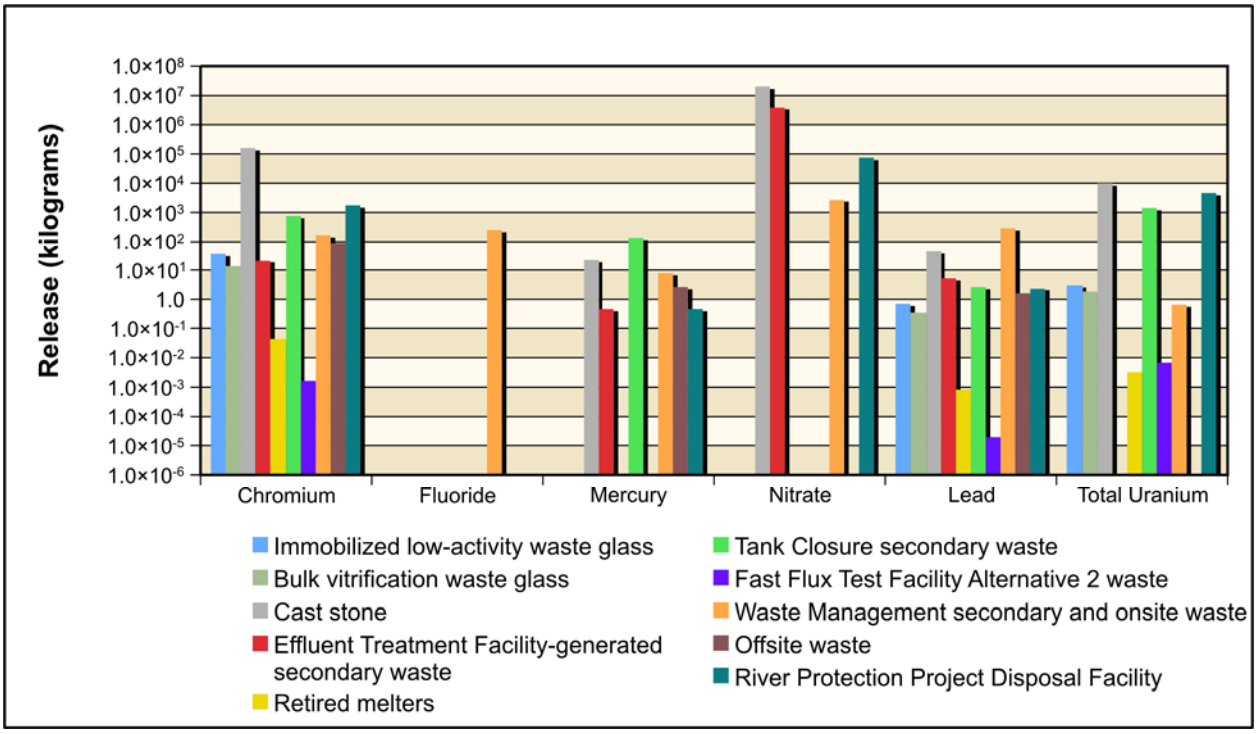


Figure M–57. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Chemical Releases to Vadose Zone

M.4.3.2.6 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-F

Disposal Group 1, Subgroup 1-F, addresses the waste resulting from Tank Closure Alternative 5, onsite non-CERCLA sources, FFTF decommissioning, waste management and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- Sulfate grout
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 5 because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, are indicated in Figures M–58 and M–59.

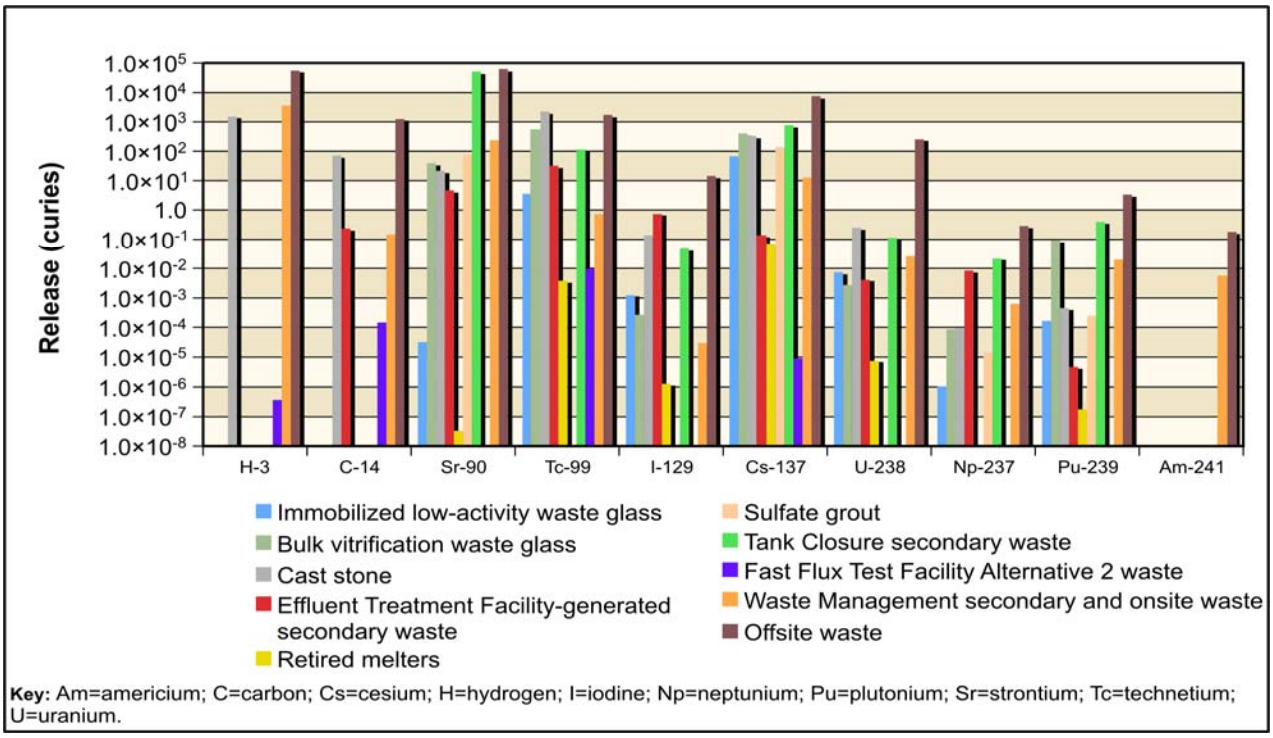


Figure M–58. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Radiological Releases to Vadose Zone

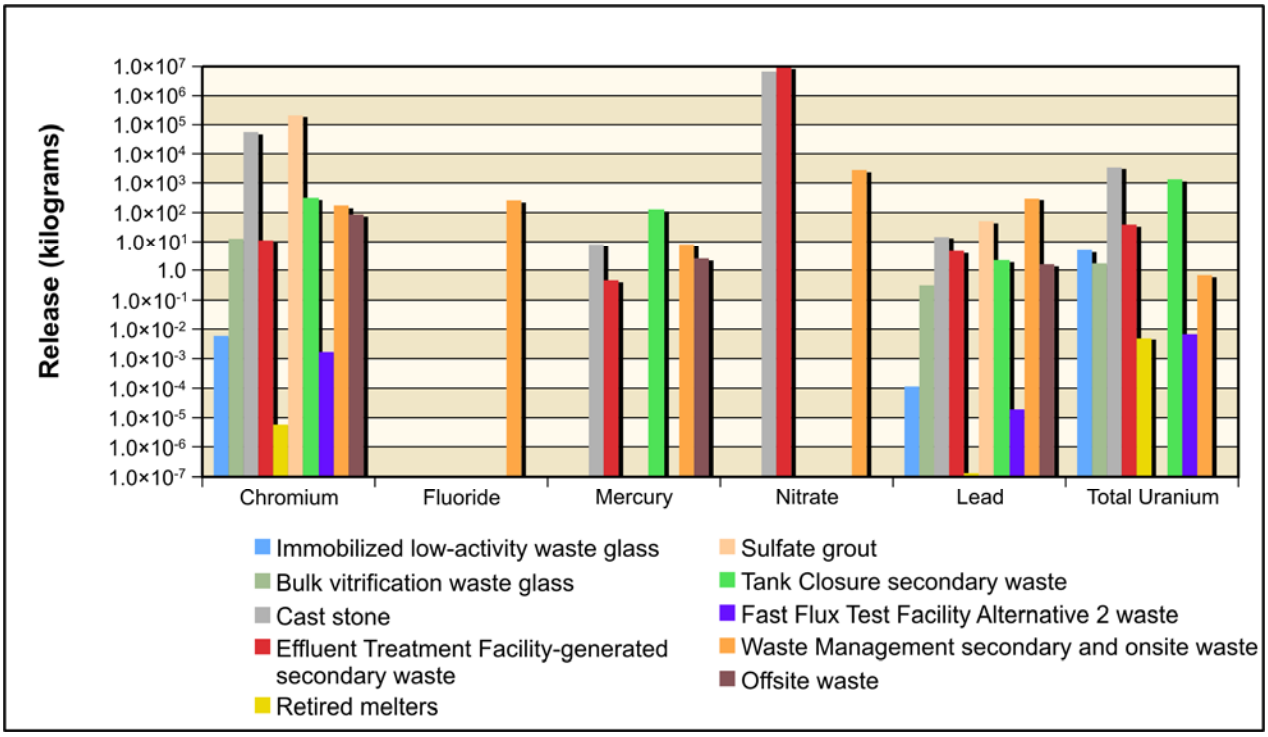


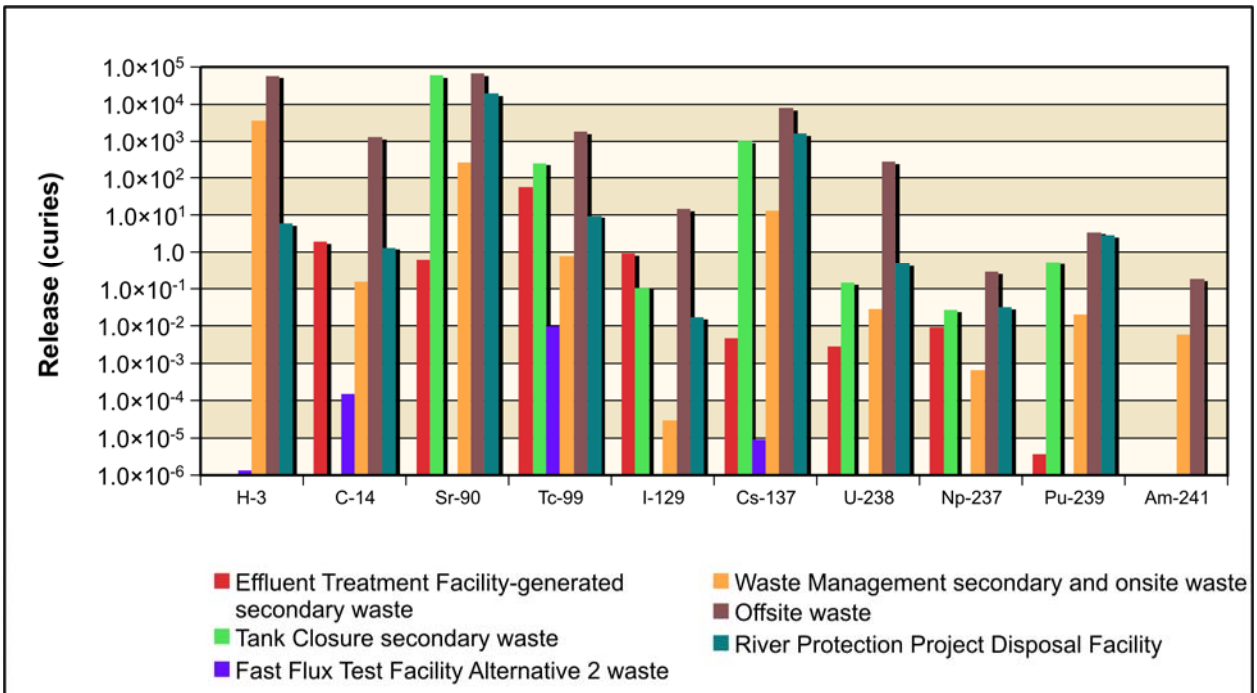
Figure M–59. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Chemical Releases to Vadose Zone

M.4.3.2.7 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-G

Disposal Group 1, Subgroup 1-G, addresses the waste resulting from Tank Closure Alternative 6C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6C. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, are indicated in Figures M–60 and M–61.



Key: Am=americium; C=carbon; Cs=cesium; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–60. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Radiological Releases to Vadose Zone

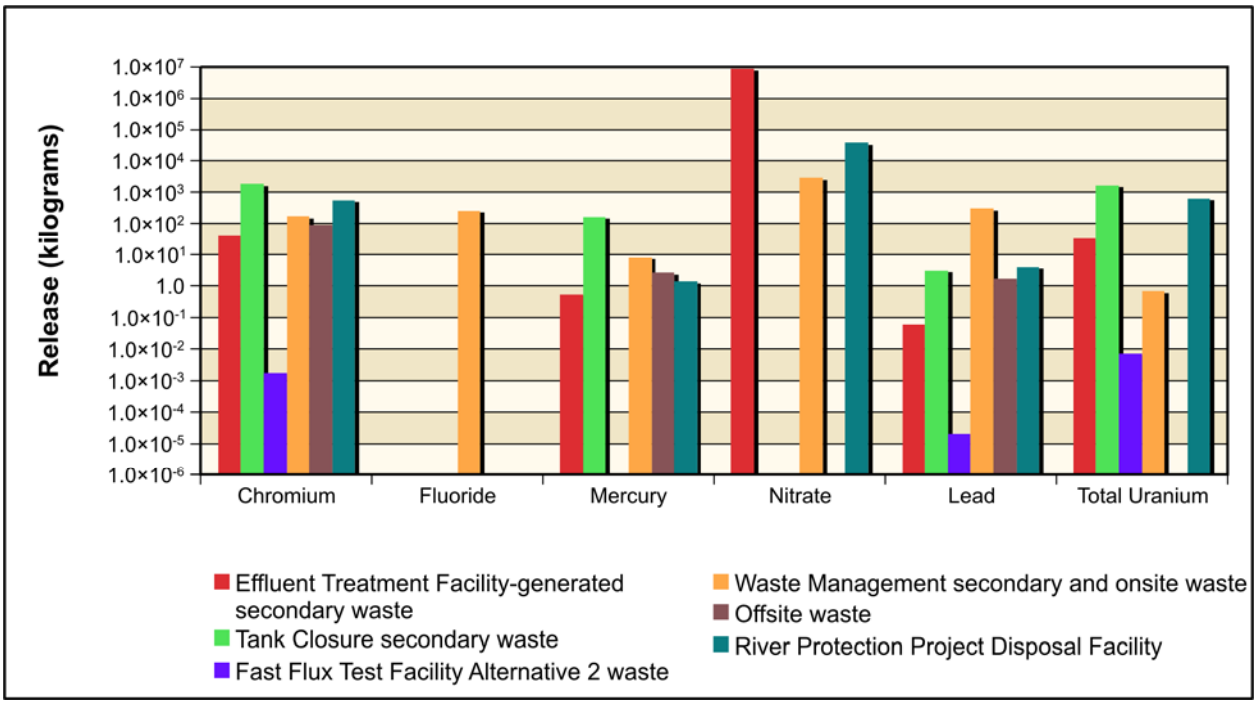


Figure M–61. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Chemical Releases to Vadose Zone

M.4.3.2.8 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 2, Subgroup 2-A

Disposal Group 2, Subgroup 2-A, addresses the waste resulting from Tank Closure Alternative 2A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 2A because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, are indicated in Figures M–62 and M–63.

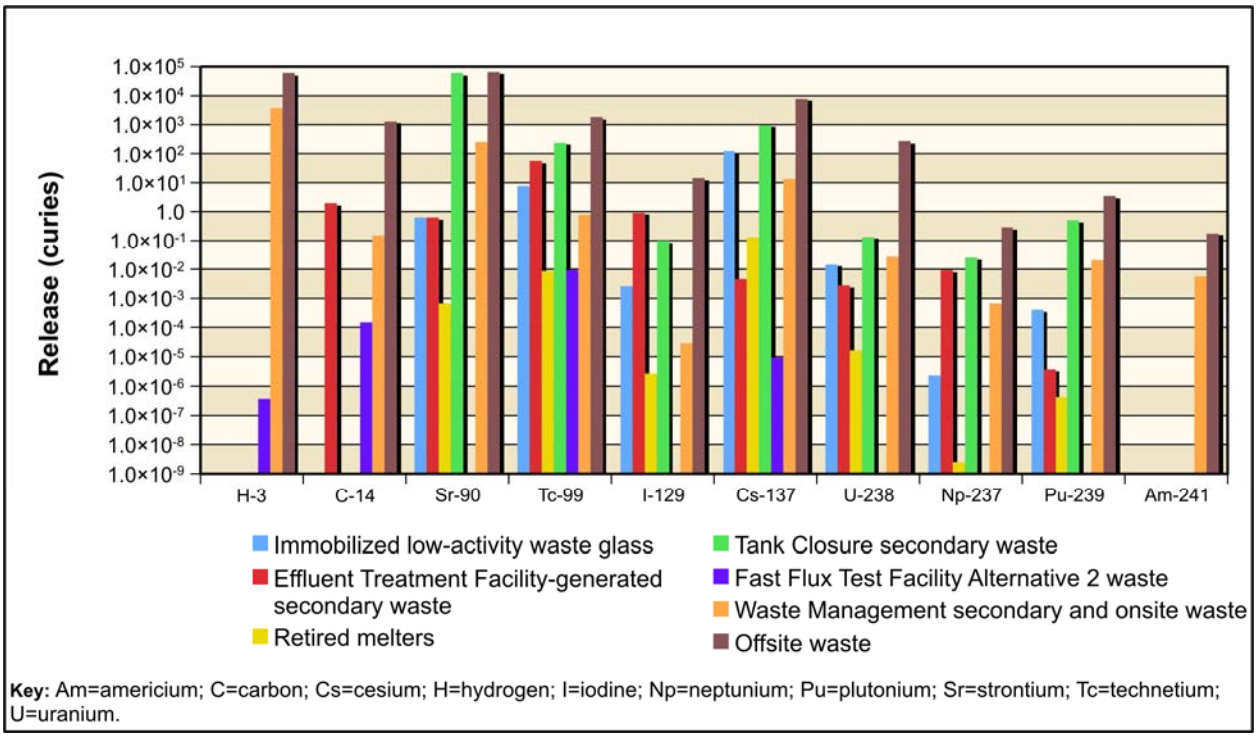


Figure M–62. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Radiological Releases to Vadose Zone

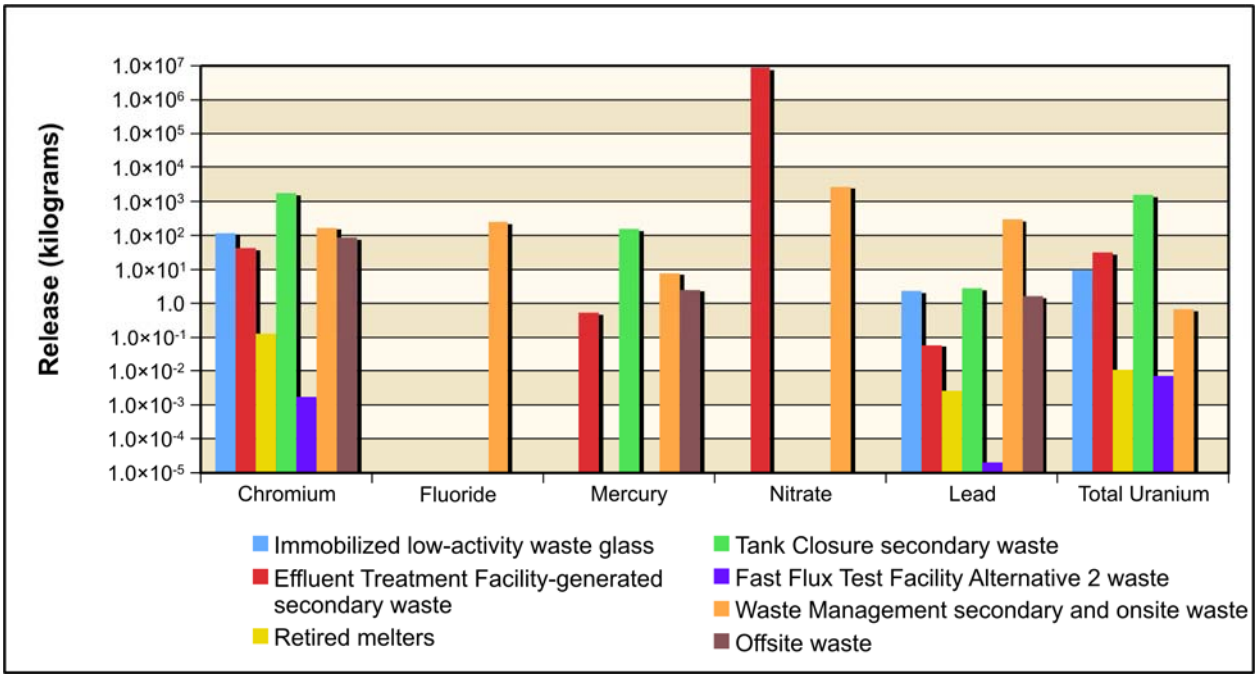


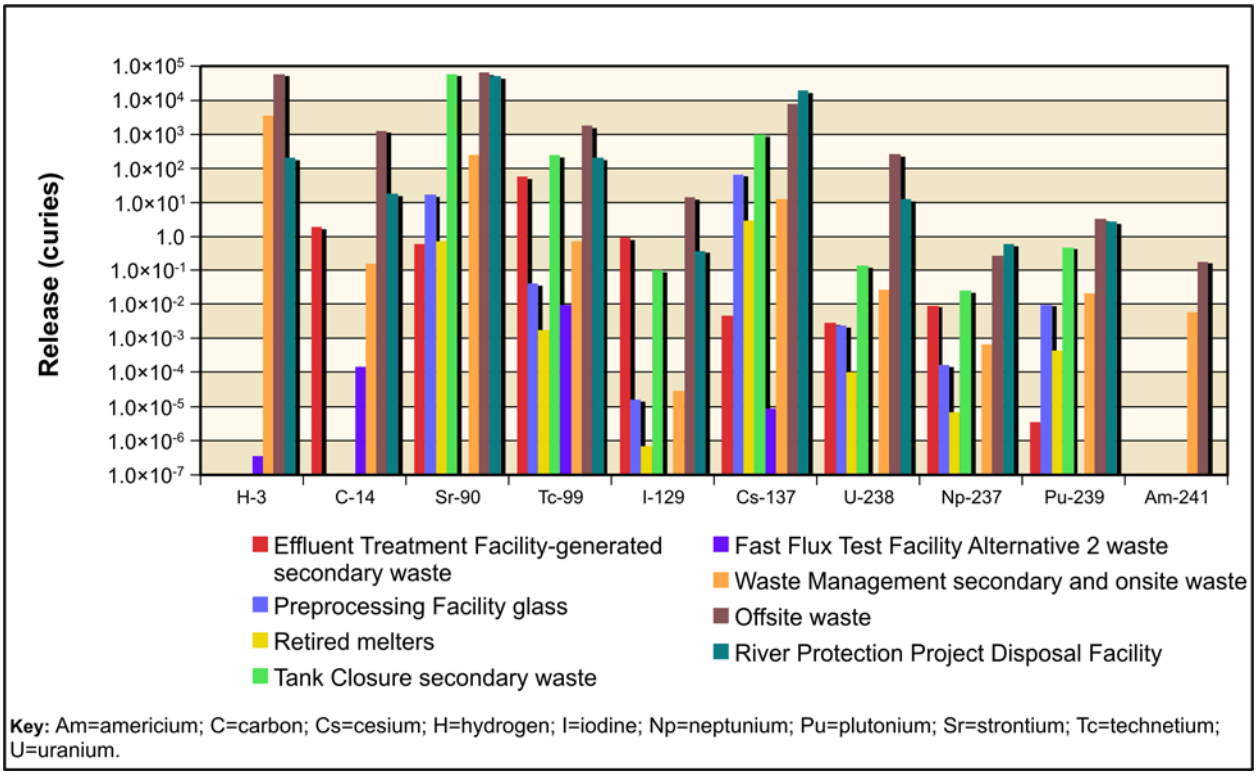
Figure M–63. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Chemical Releases to Vadose Zone

M.4.3.2.9 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 2, Subgroup 2-B

Disposal Group 2, Subgroup 2-B, addresses the waste resulting from Tank Closure Alternative 6B, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- Preprocessing Facility (PPF) glass
- PPF melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6B, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base and Option Cases, are indicated in Figures M–64 through M–67.



Key: Am=americium; C=carbon; Cs=cesium; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–64. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Radiological Releases to Vadose Zone

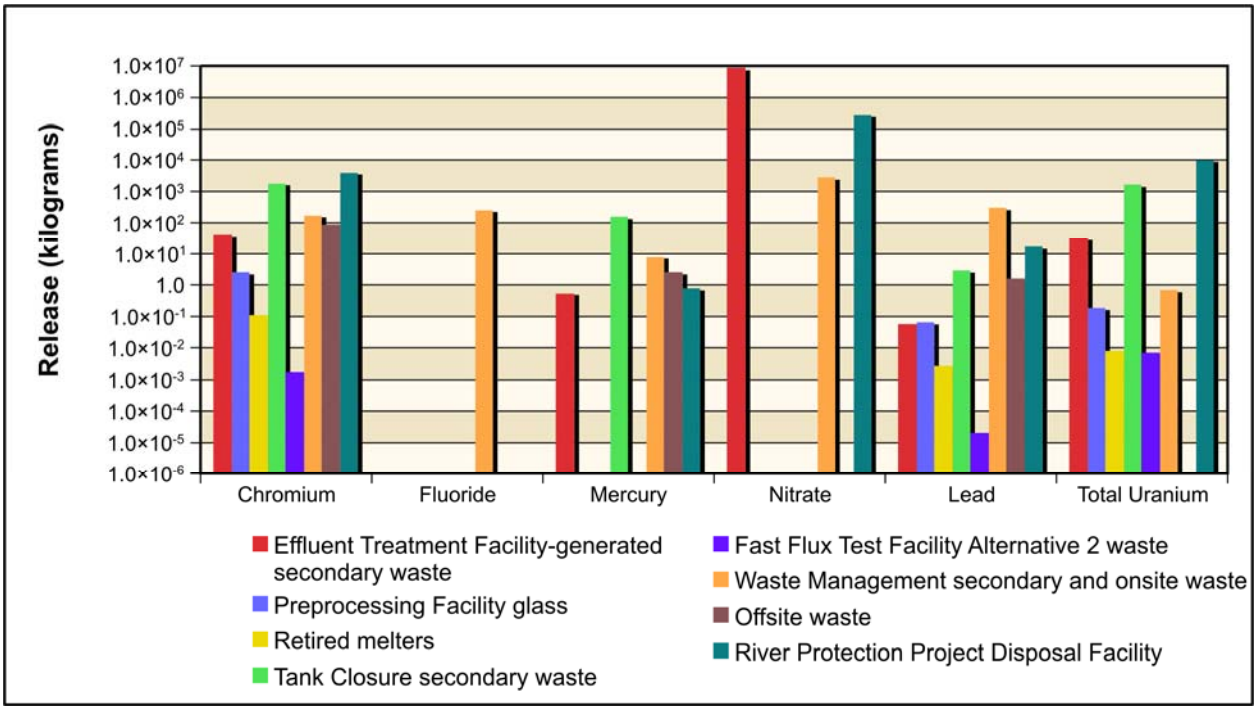
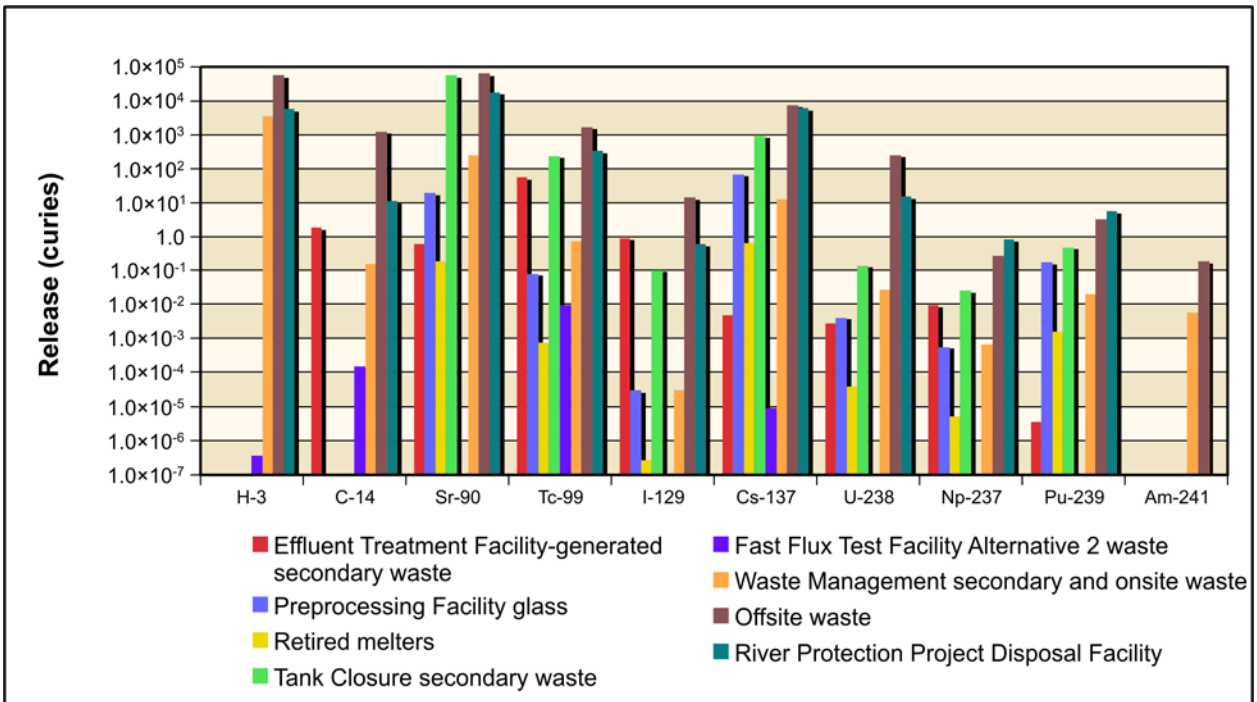


Figure M–65. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Chemical Releases to Vadose Zone



Key: Am=americium; C=carbon; Cs=cesium; H=hydrogen; I=iodine; Np=neptunium; Pu=plutonium; Sr=strontium; Tc=technetium; U=uranium.

Figure M–66. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Radiological Releases to Vadose Zone

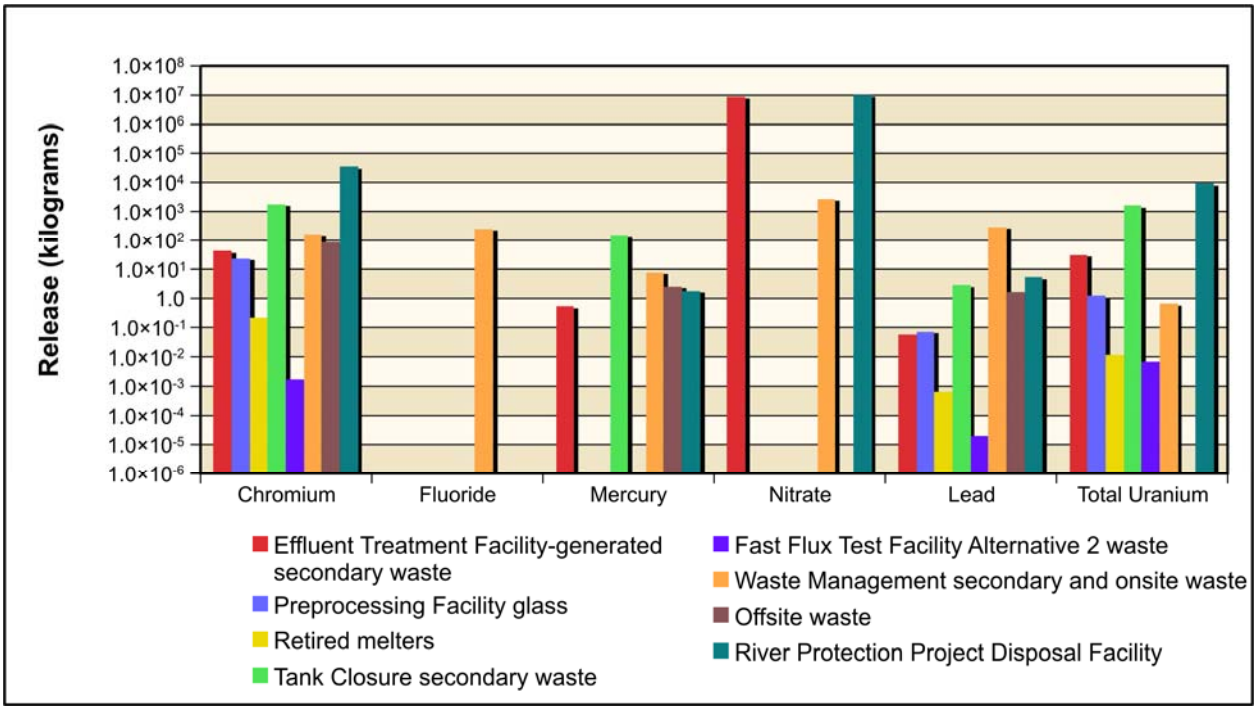


Figure M–67. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Chemical Releases to Vadose Zone

M.4.3.2.10 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 3

Disposal Group 3 addresses the waste resulting from Tank Closure Alternative 6A, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6A, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 3, Base and Option Cases, are indicated in Figures M–68 through M–71.

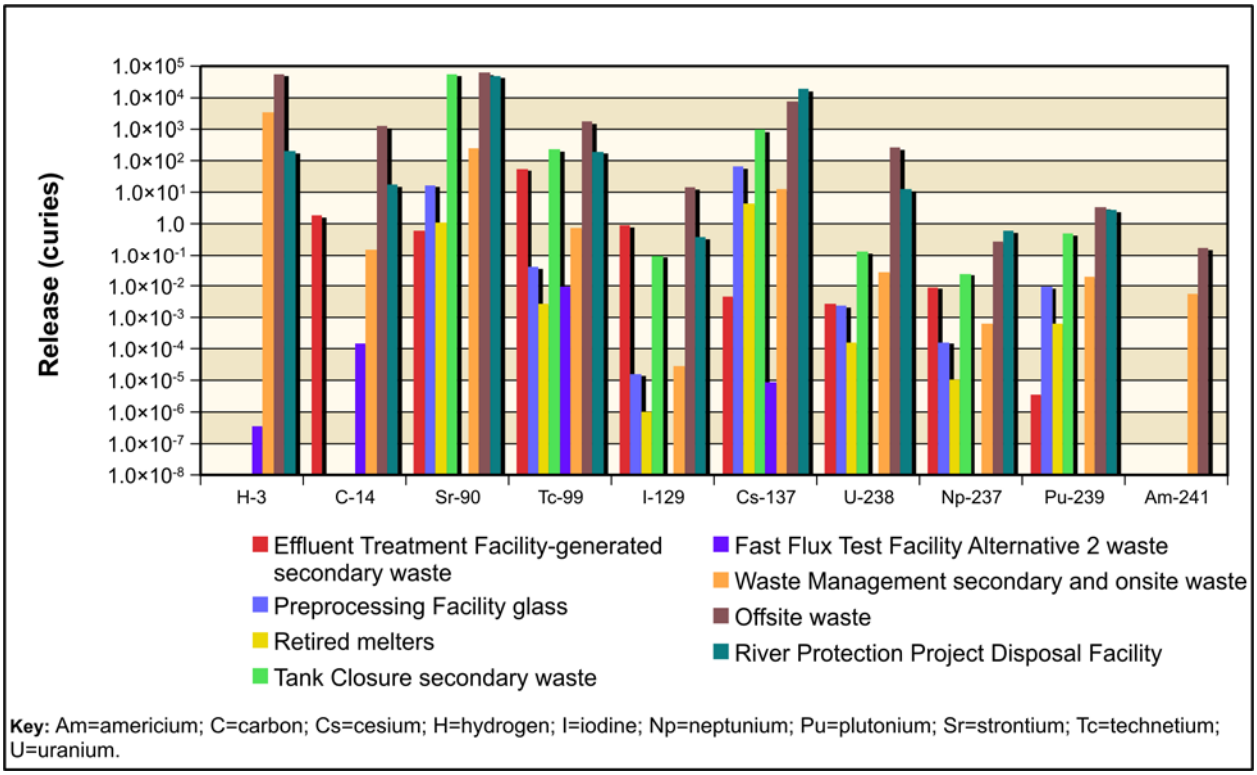


Figure M–68. Waste Management Alternative 2, Disposal Group 3, Base Case, Radiological Releases to Vadose Zone

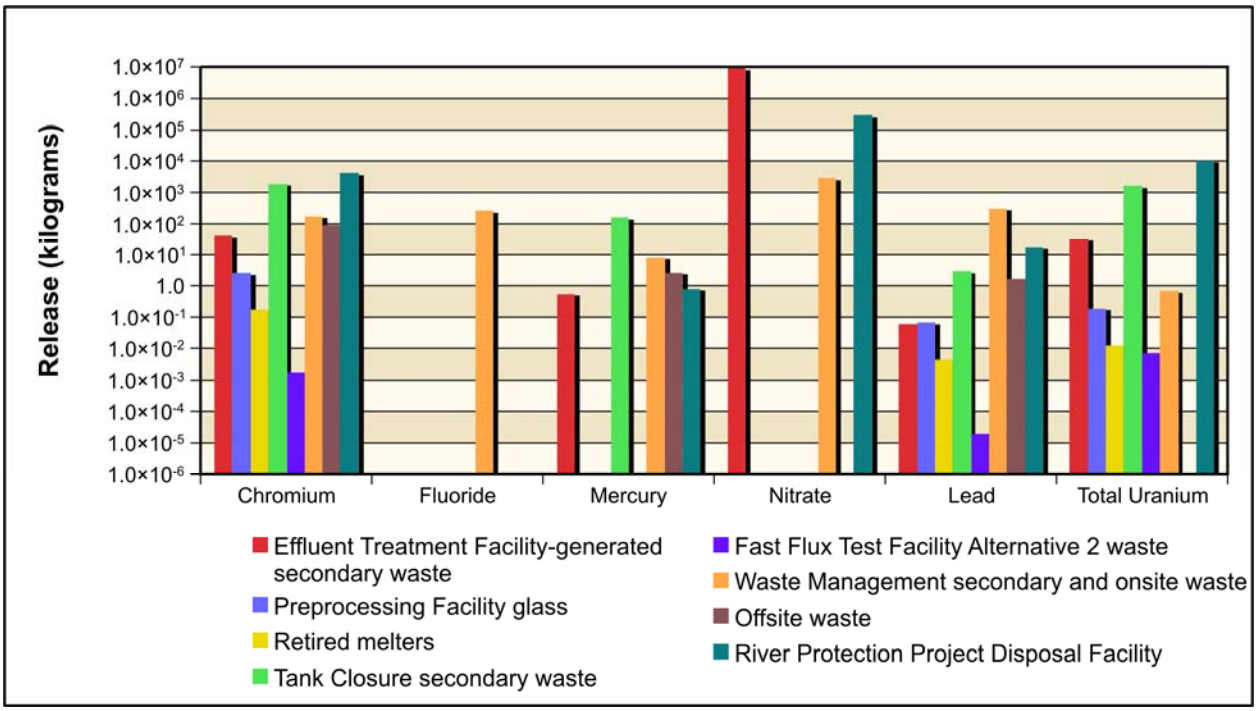


Figure M–69. Waste Management Alternative 2, Disposal Group 3, Base Case, Chemical Releases to Vadose Zone

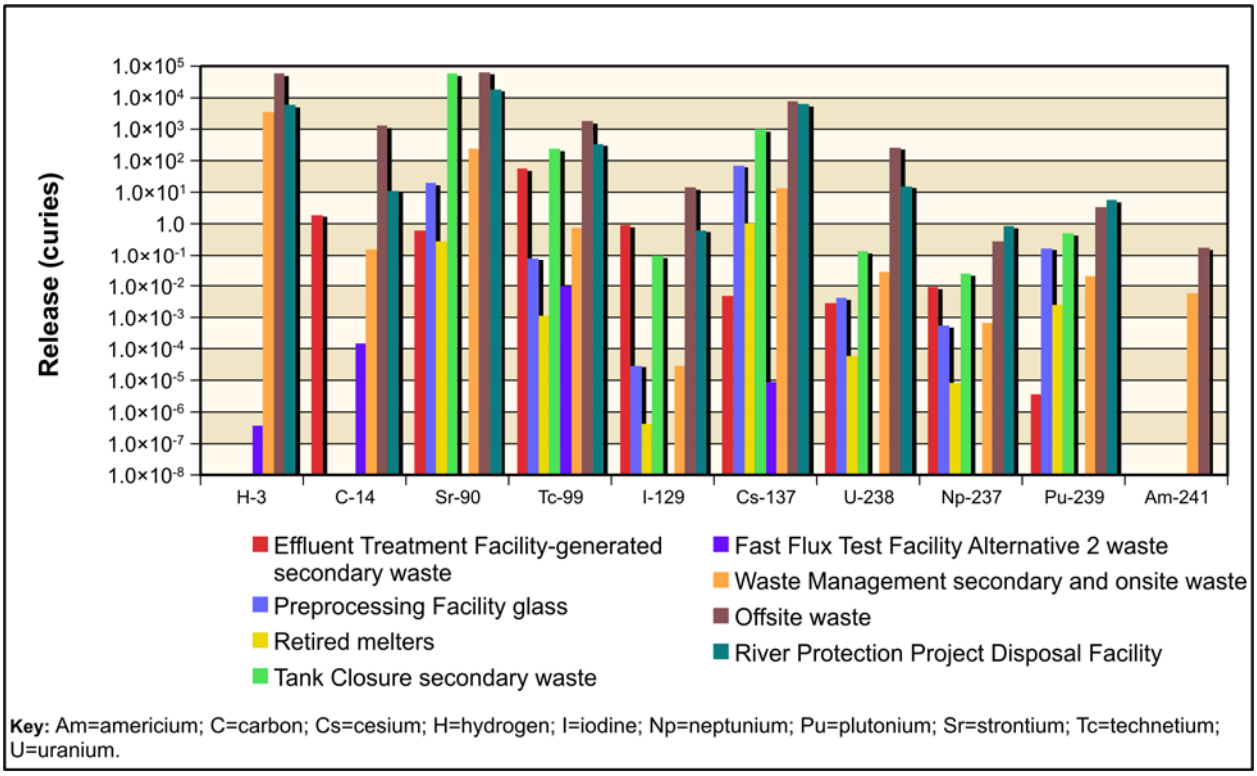


Figure M–70. Waste Management Alternative 2, Disposal Group 3, Option Case, Radiological Releases to Vadose Zone

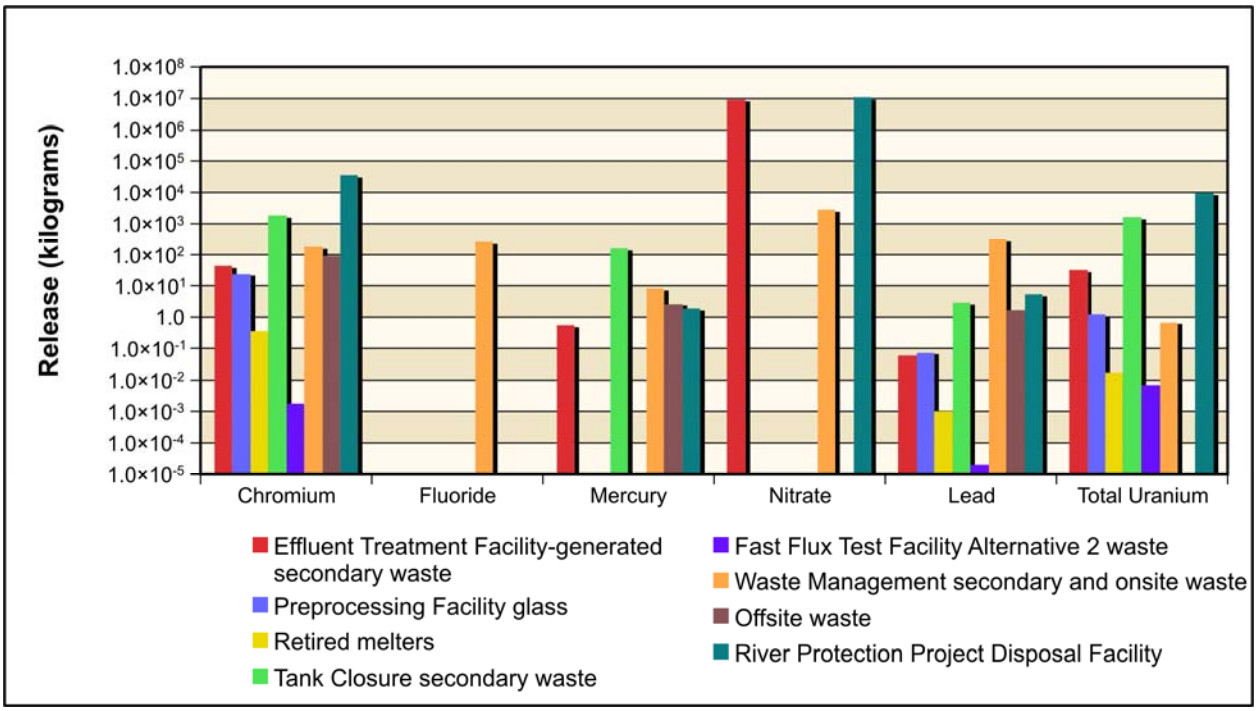


Figure M–71. Waste Management Alternative 2, Disposal Group 3, Option Case, Chemical Releases to Vadose Zone

M.4.3.3 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas

Under Waste Management Alternative 3, the waste from tank treatment operations would be disposed of in IDF-East, and onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites would be disposed of in IDF-West. Waste from tank farm cleanup operations would be disposed of in the RPPDF. As a result, the waste disposed of in these three facilities would become available for release to the environment. Because of the different waste types that result from the Tank Closure action alternatives, three disposal groups were considered to account for the different IDF-East sizes and operational time periods. In addition, within these three disposal groups, subgroups were identified to allow consideration of the different waste types resulting from the Tank Closure alternatives.

The amount of waste disposed of at IDF-West under each subgroup is identical. Potential releases to the vadose zone from IDF-West under Waste Management Alternative 3 are indicated in Figures M–72 and M–73, only presented once for all disposal groups for Waste Management Alternative 3.

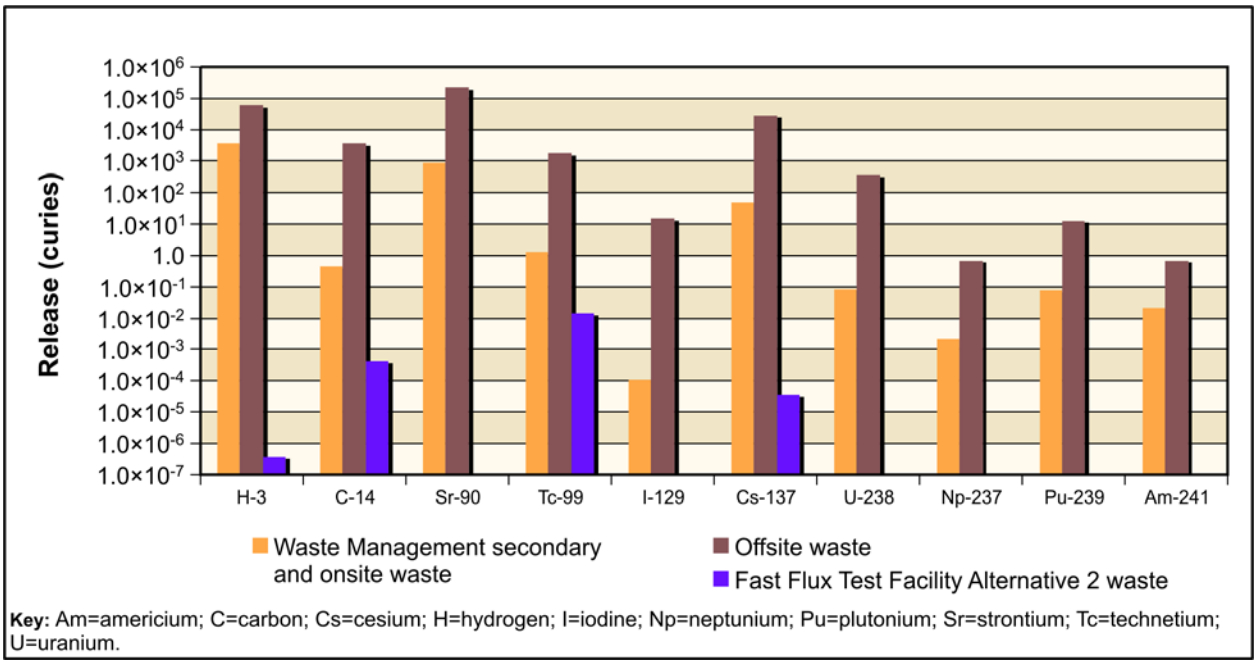


Figure M–72. Waste Management Alternative 3, All Disposal Groups, 200-West Area Integrated Disposal Facility Radiological Releases to Vadose Zone

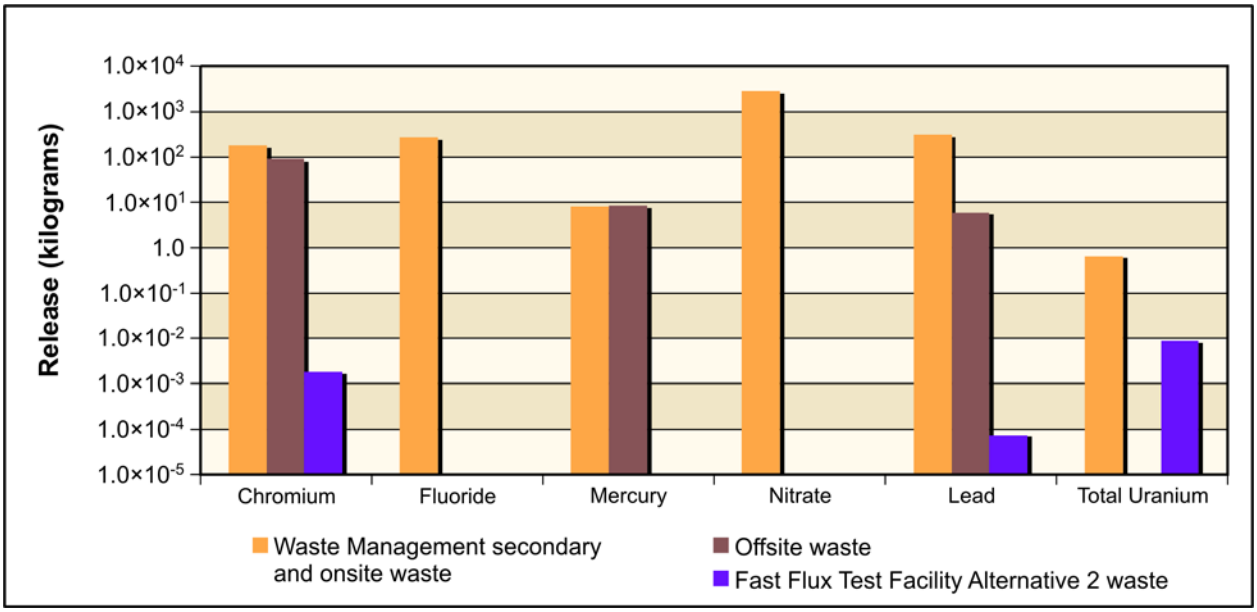


Figure M–73. Waste Management Alternative 3, All Disposal Groups, 200-West Area Integrated Disposal Facility Chemical Releases to Vadose Zone

Potential releases from IDF-East and RPPDF are discussed in the following sections.

M.4.3.3.1 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-A

Disposal Group 1, Subgroup 1-A, addresses the waste resulting from Tank Closure Alternative 2B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 2B. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, are indicated in Figures M–74 and M–75.

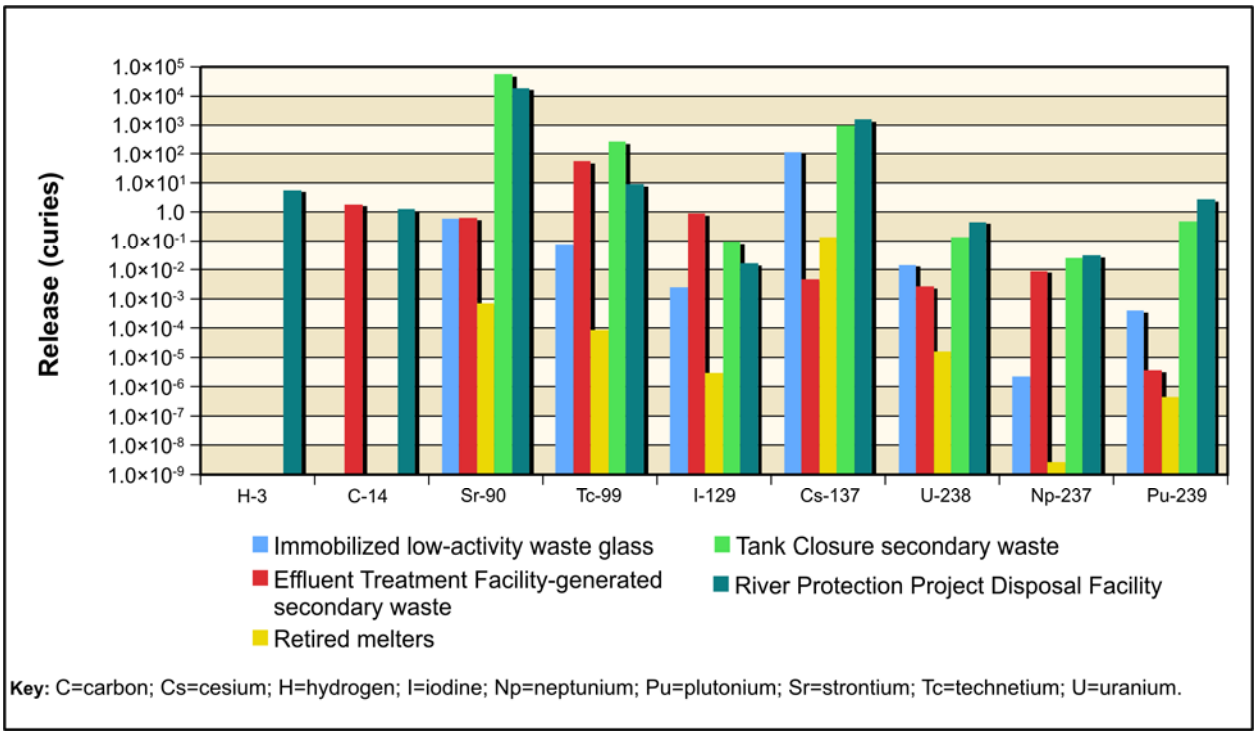


Figure M–74. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

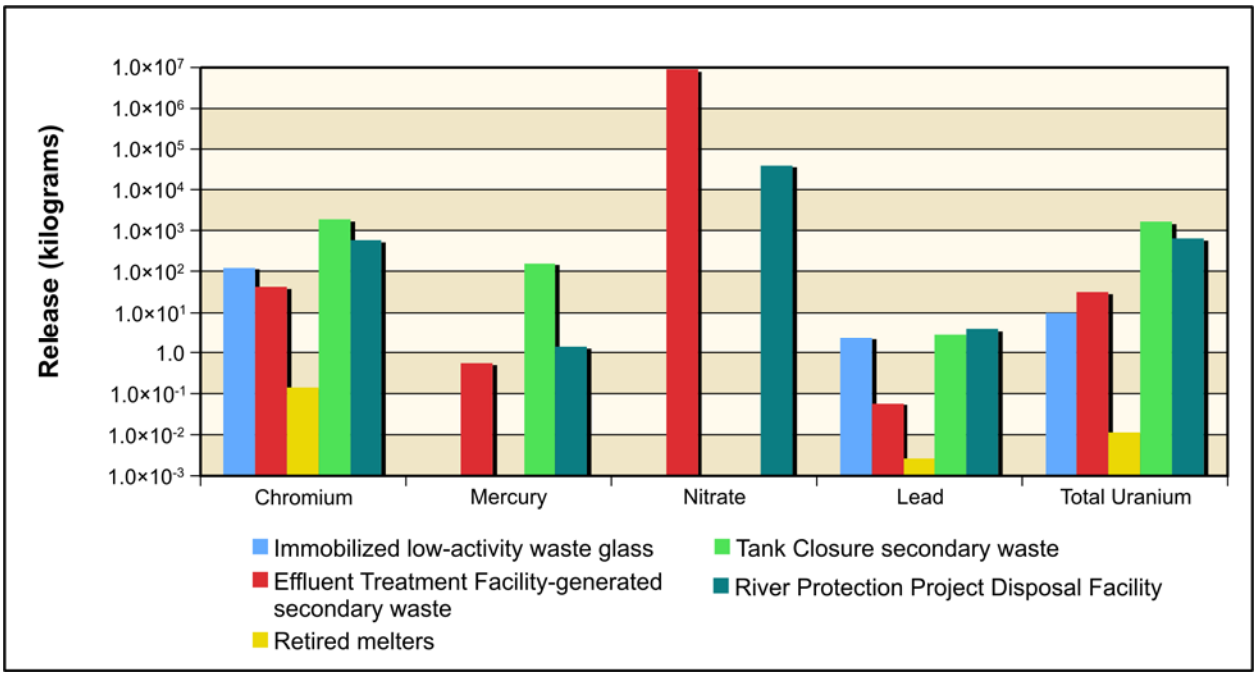


Figure M–75. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.2 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-B

Disposal Group 1, Subgroup 1-B, addresses the waste resulting from Tank Closure Alternative 3A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3A. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, are indicated in Figures M–76 and M–77.

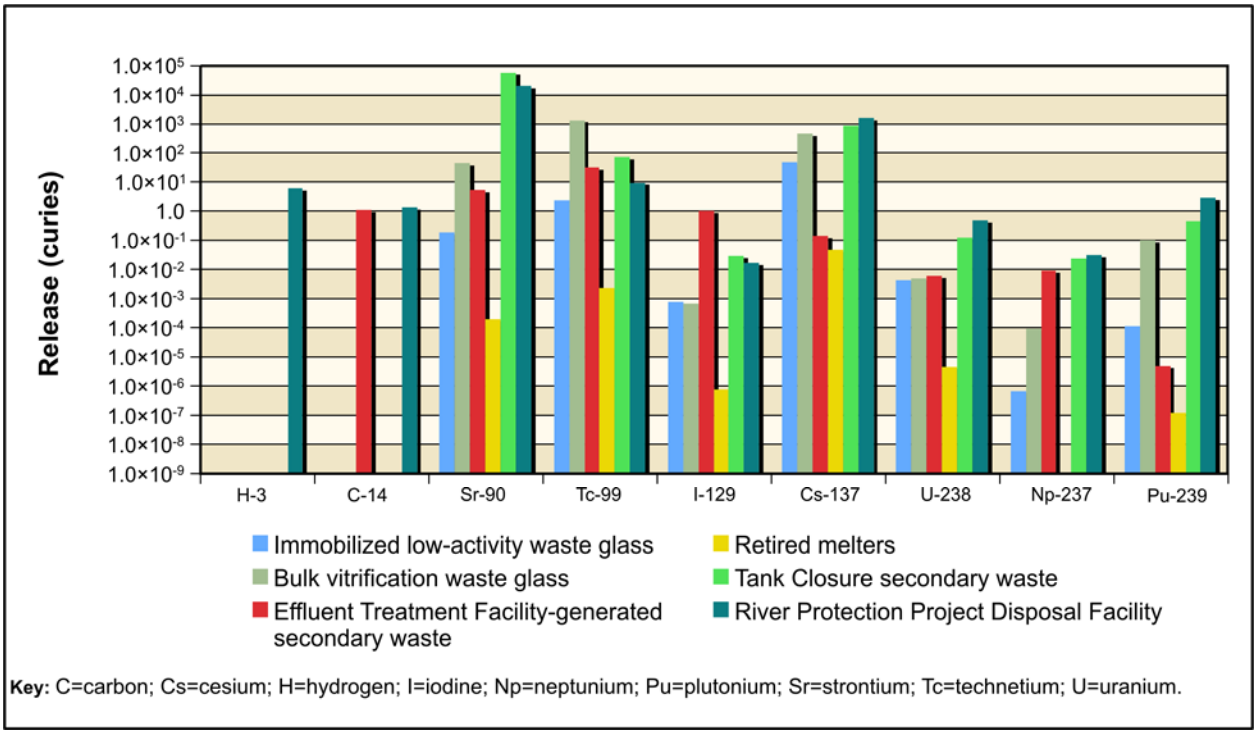


Figure M–76. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

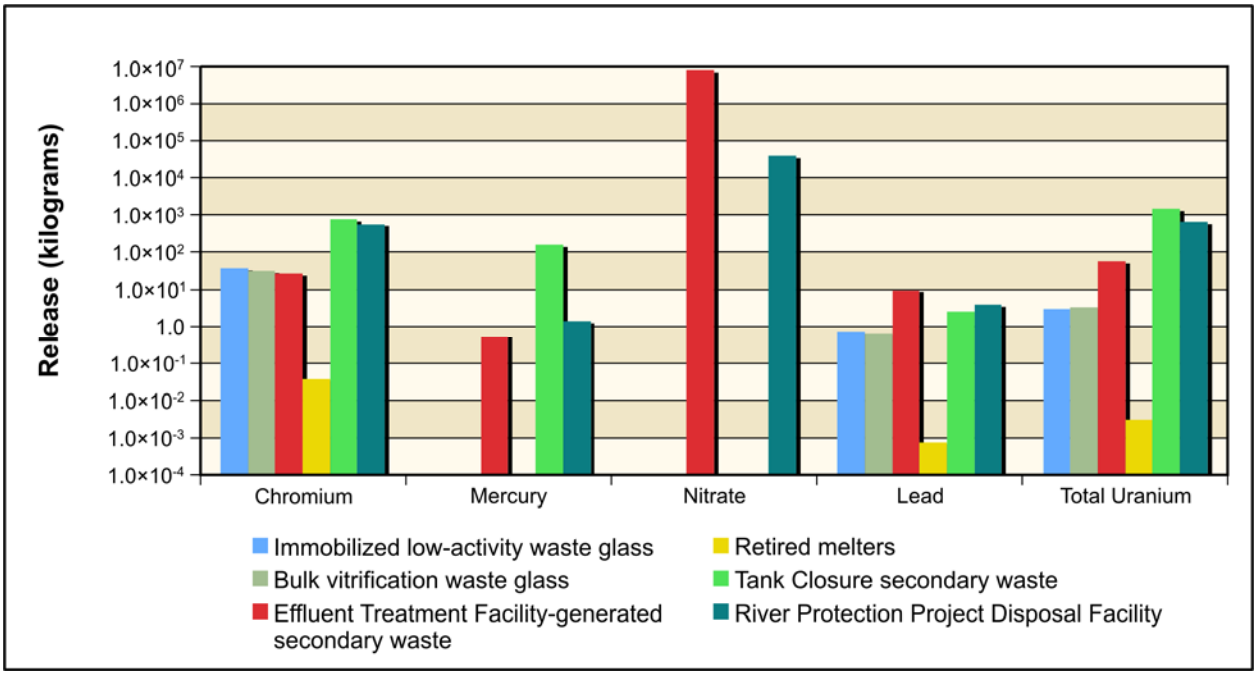


Figure M–77. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.3 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-C

Disposal Group 1, Subgroup 1-C, addresses the waste resulting from Tank Closure Alternative 3B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Cast stone
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3B. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, are indicated in Figures M–78 and M–79.

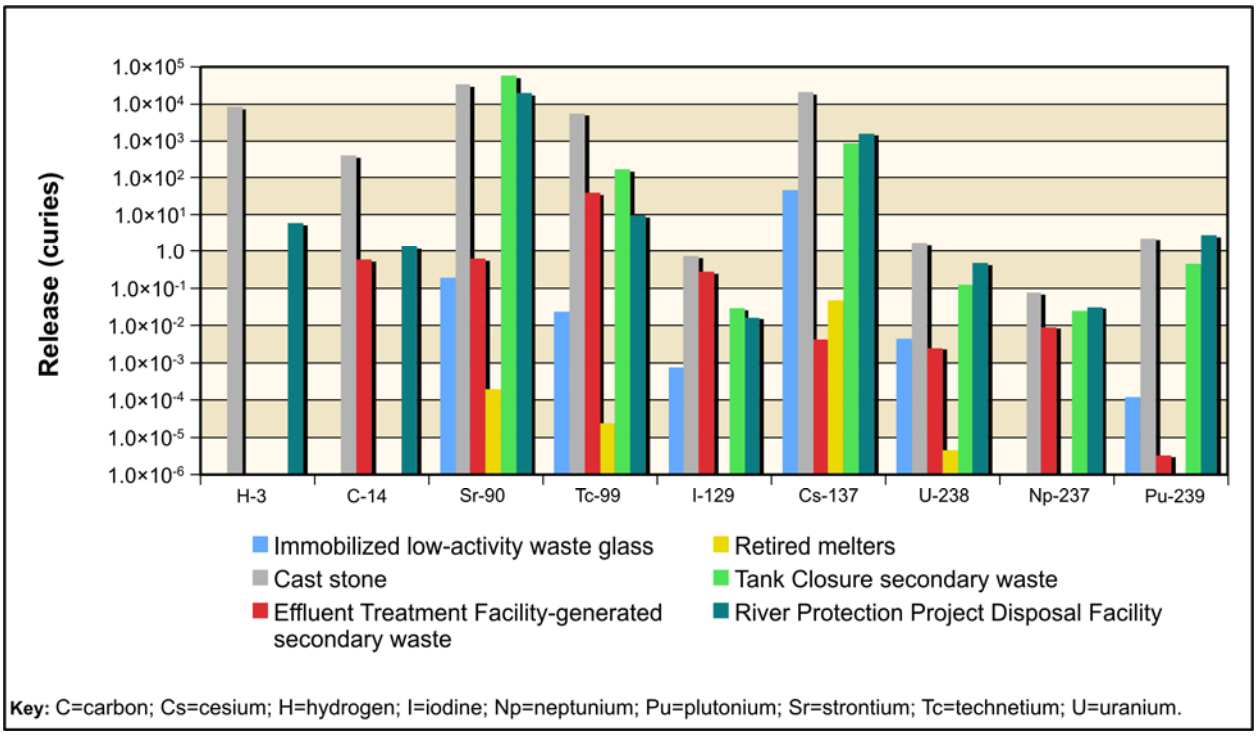


Figure M–78. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

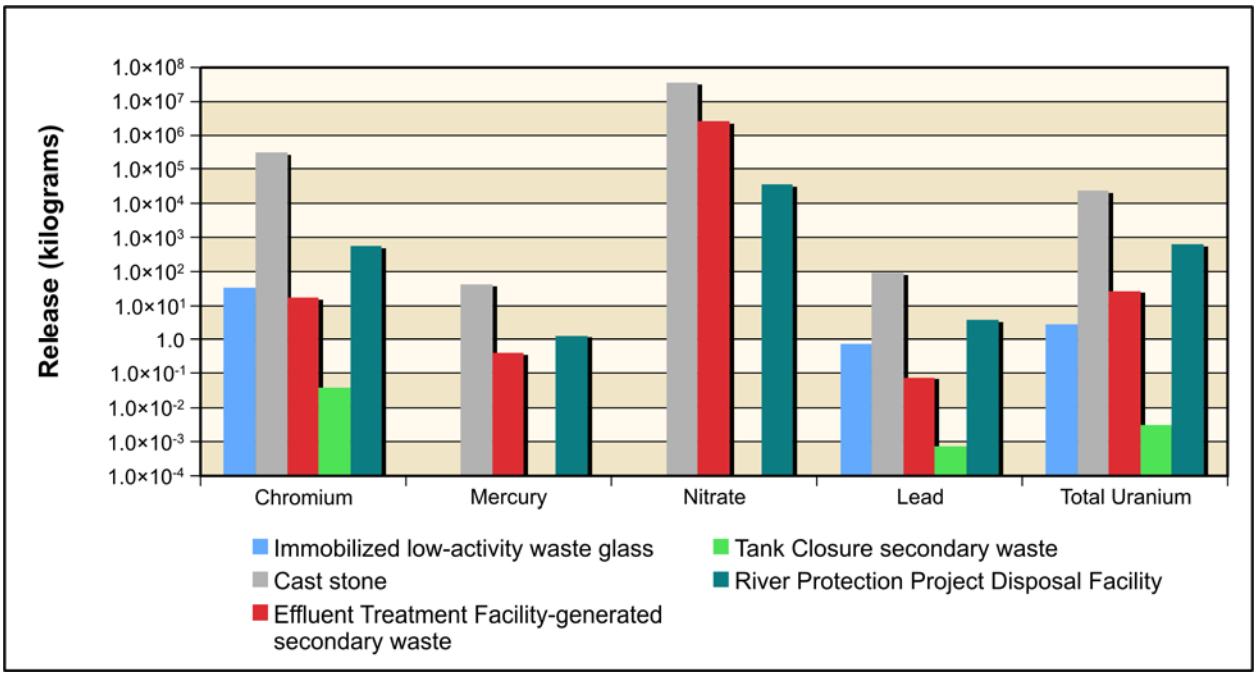


Figure M–79. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.4 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-D

Disposal Group 1, Subgroup 1-D, addresses the waste resulting from Tank Closure Alternative 3C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Steam reforming waste
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3C. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, are indicated in Figures M–80 and M–81.

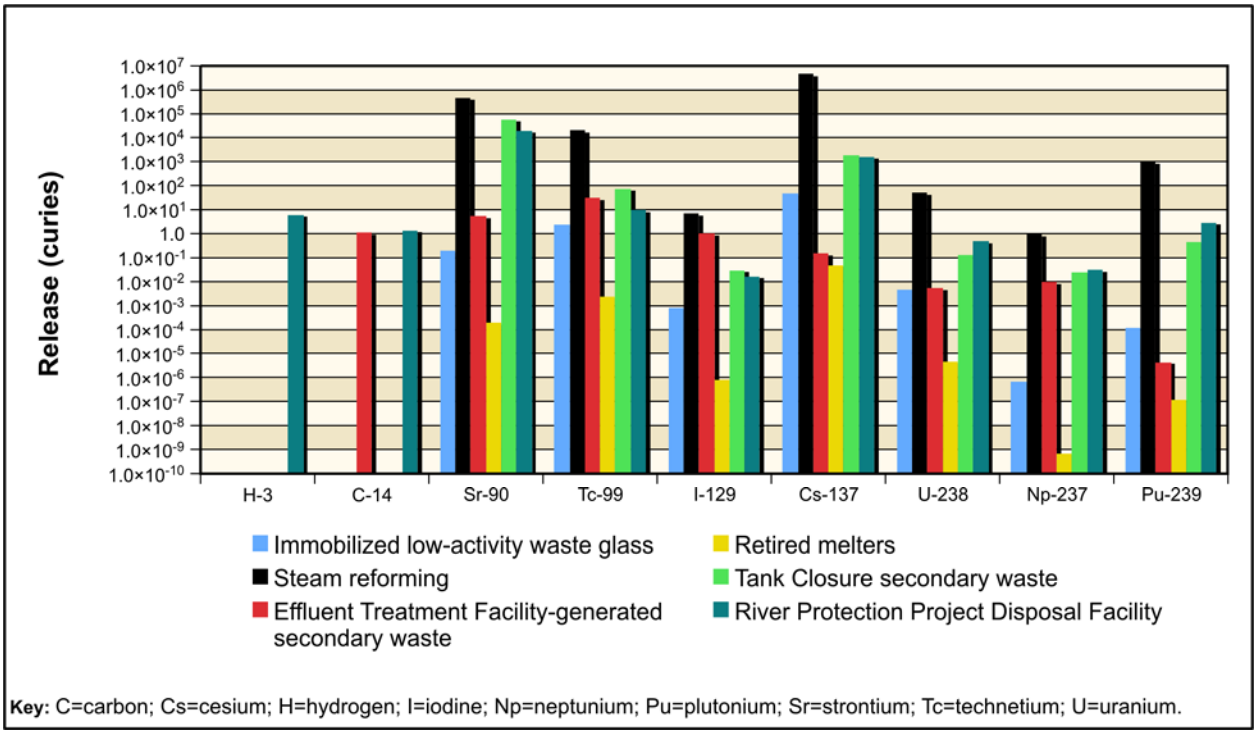


Figure M–80. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

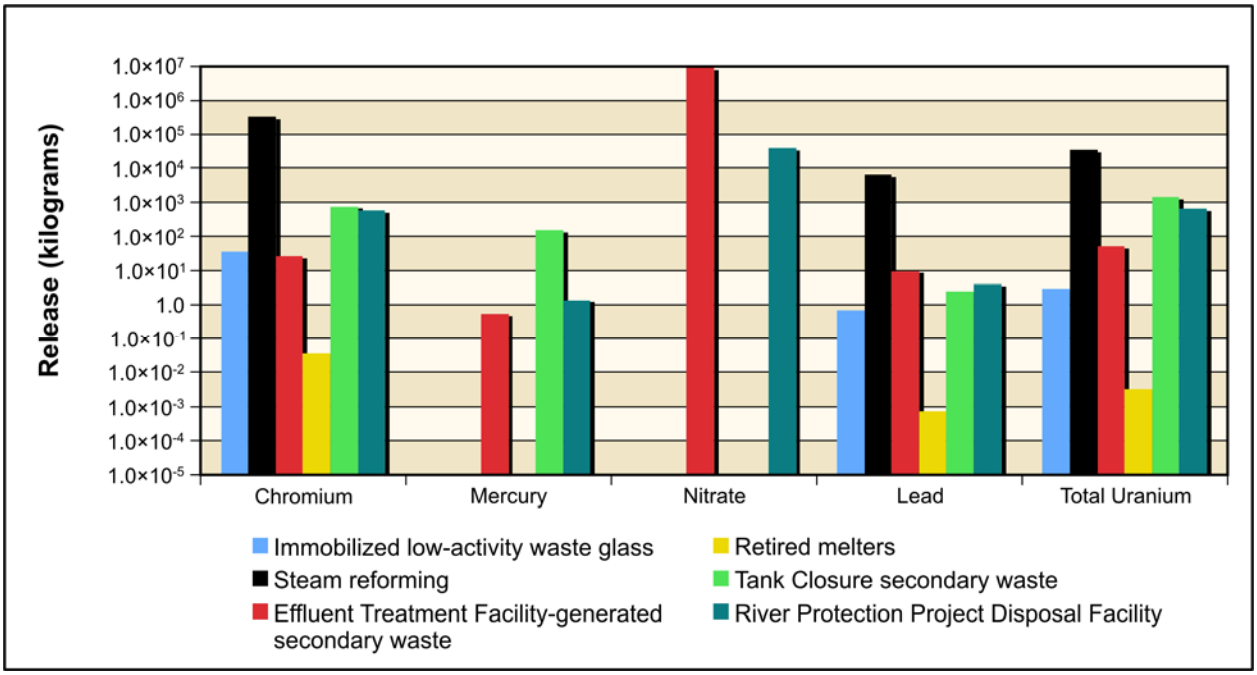


Figure M–81. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.5 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-E

Disposal Group 1, Subgroup 1-E, addresses the waste resulting from Tank Closure Alternative 4, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- ETF secondary solid waste
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 4 because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, are indicated in Figures M–82 and M–83.

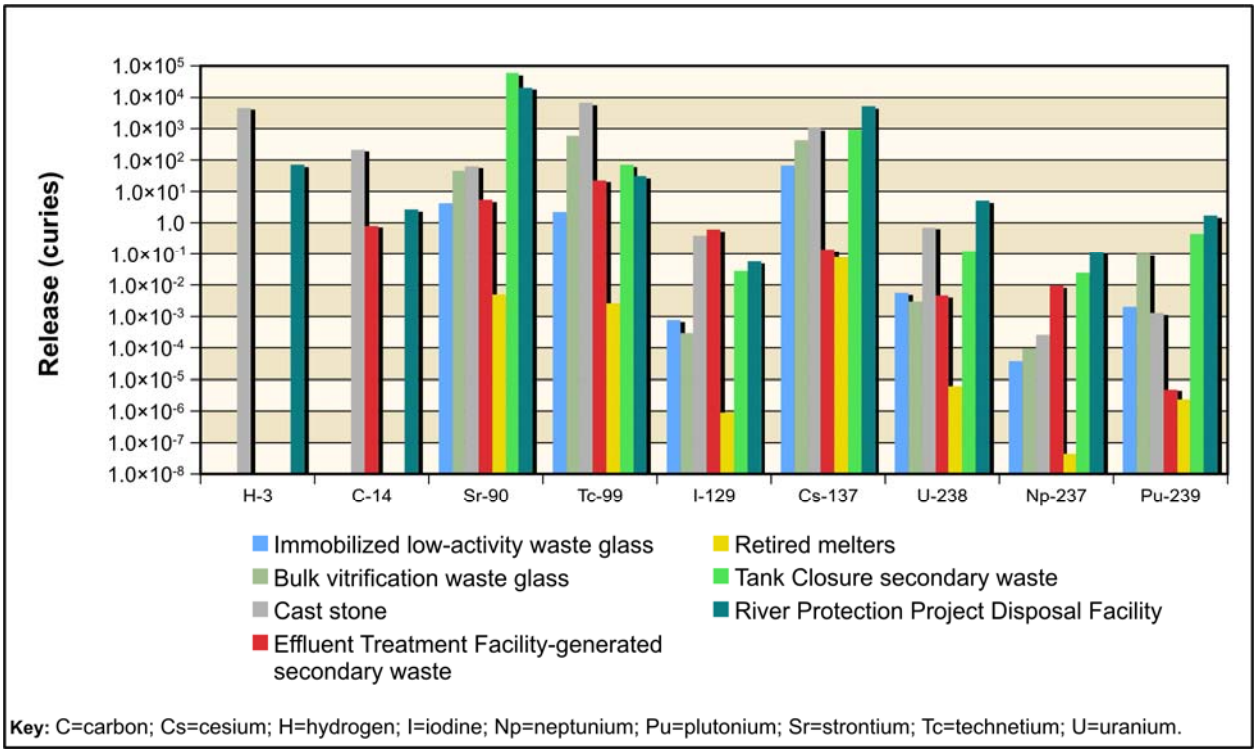


Figure M–82. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

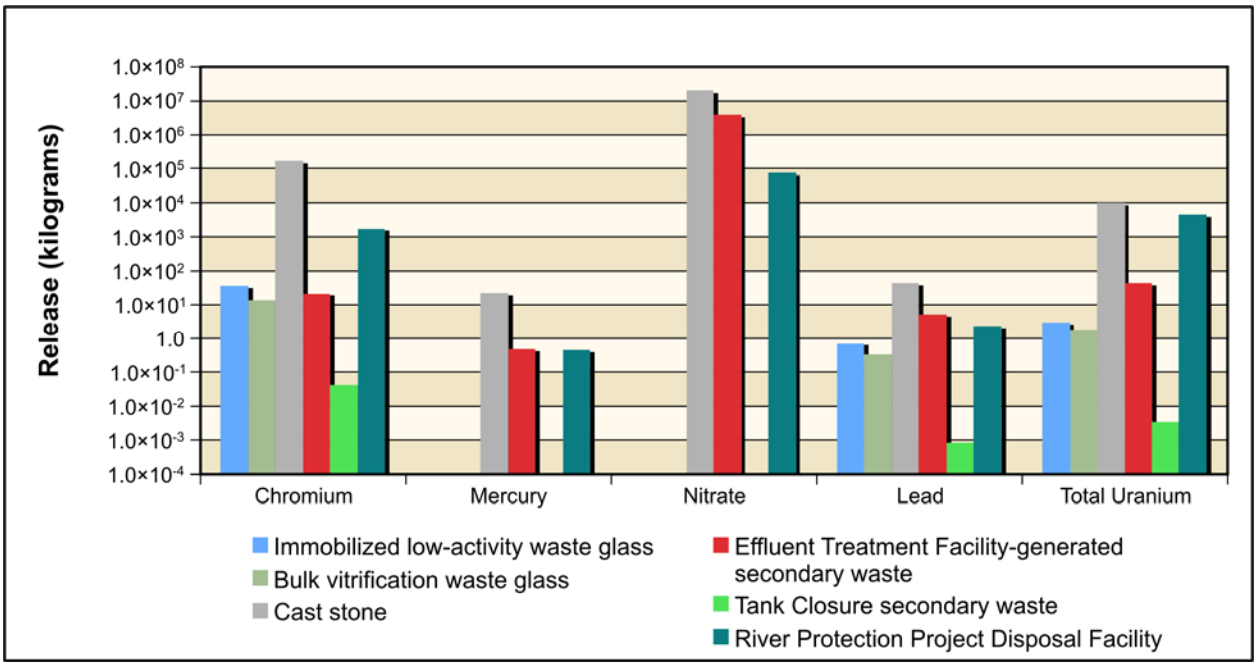


Figure M–83. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.6 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-F

Disposal Group 1, Subgroup 1-F, addresses the waste resulting from Tank Closure Alternative 5, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- Sulfate grout
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, are indicated in Figures M–84 and M–85.

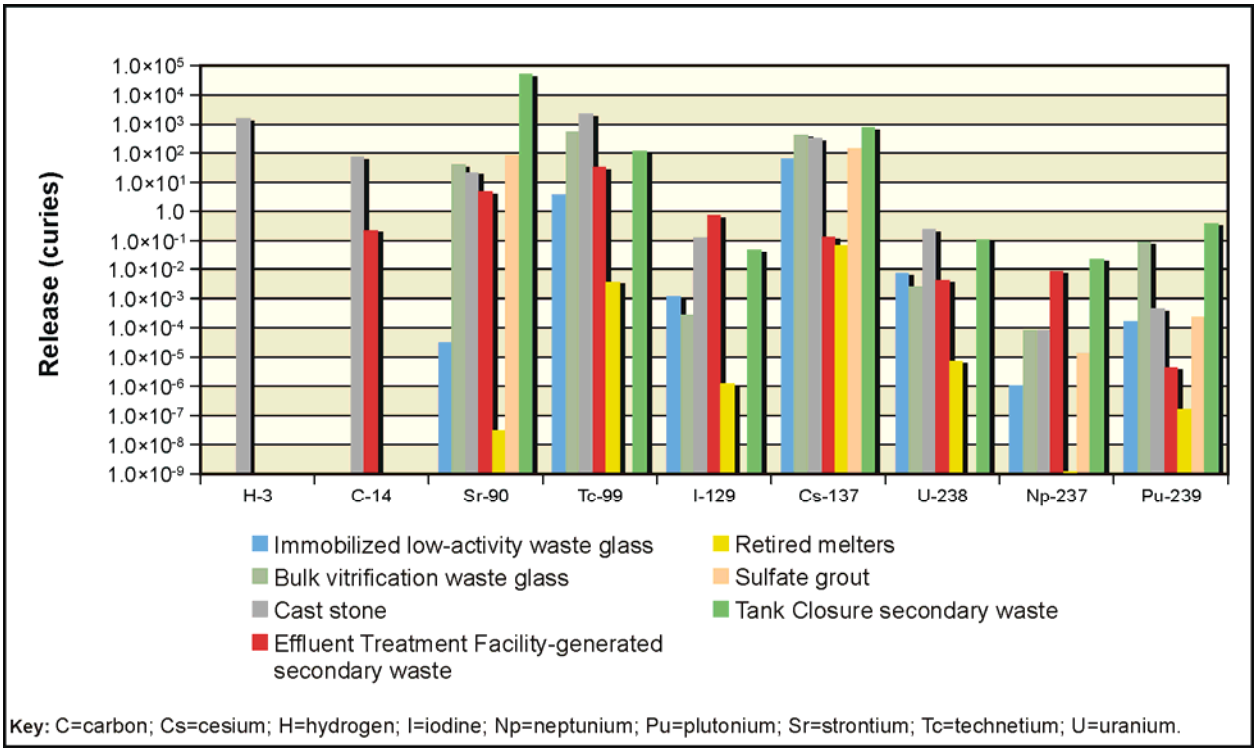


Figure M–84. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

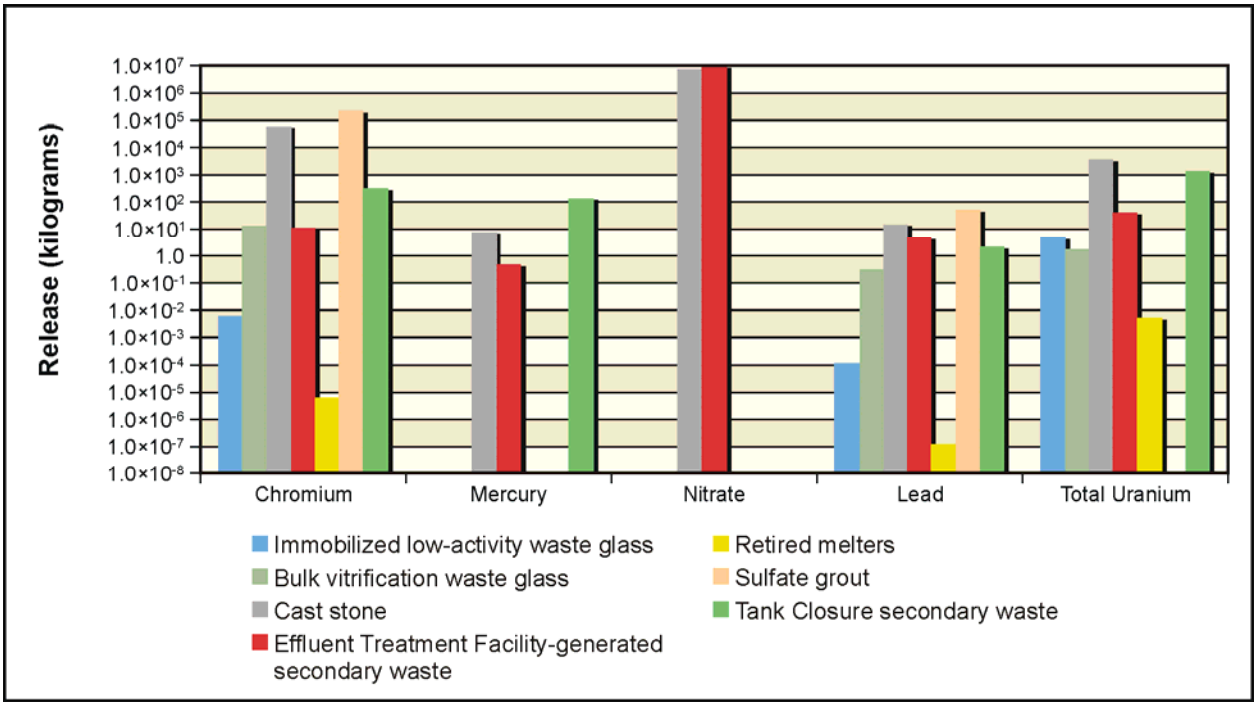


Figure M–85. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.7 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-G

Disposal Group 1, Subgroup 1-G, addresses the waste resulting from Tank Closure Alternative 6C, onsite non–CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6C. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, are indicated in Figures M–86 and M–87.

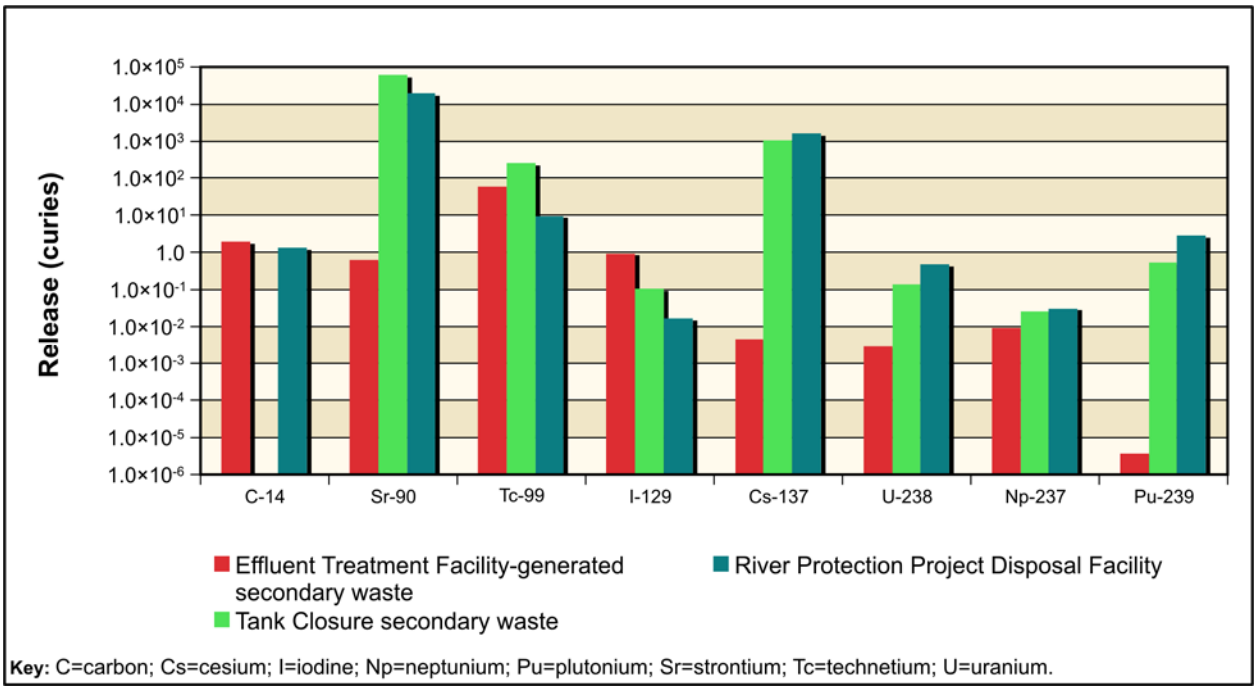


Figure M–86. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

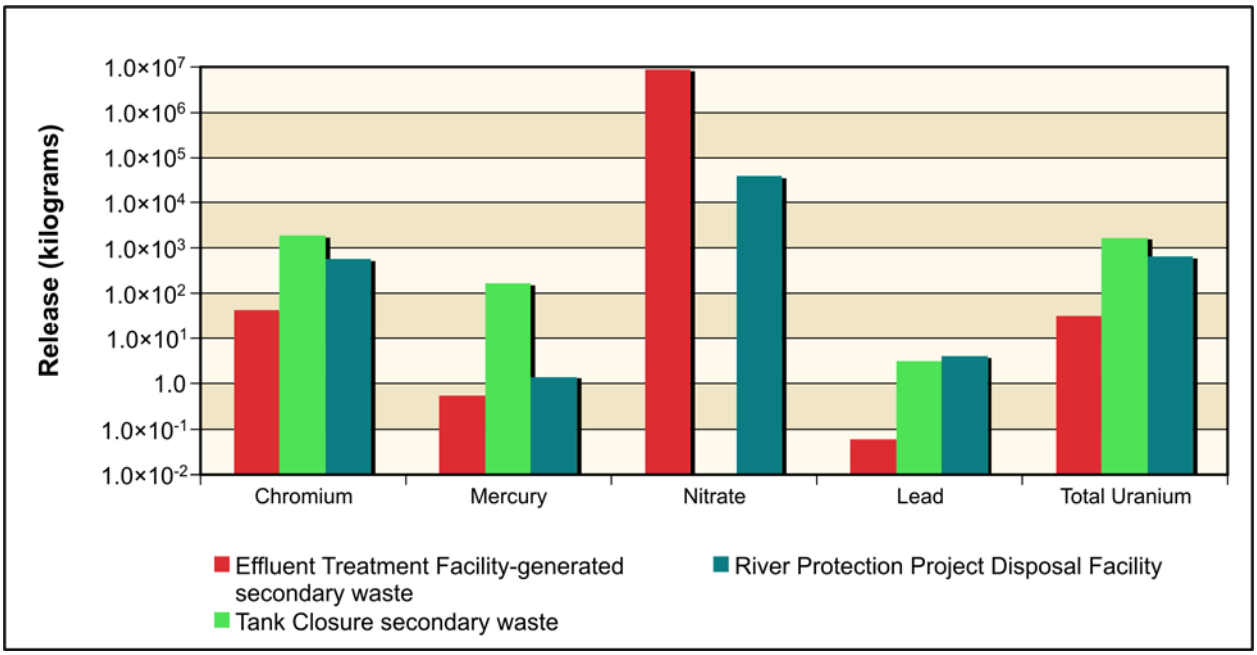


Figure M–87. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.8 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 2, Subgroup 2-A

Disposal Group 2, Subgroup 2-A, addresses the waste resulting from Tank Closure Alternative 2A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 2A because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, are indicated in Figures M–88 and M–89.

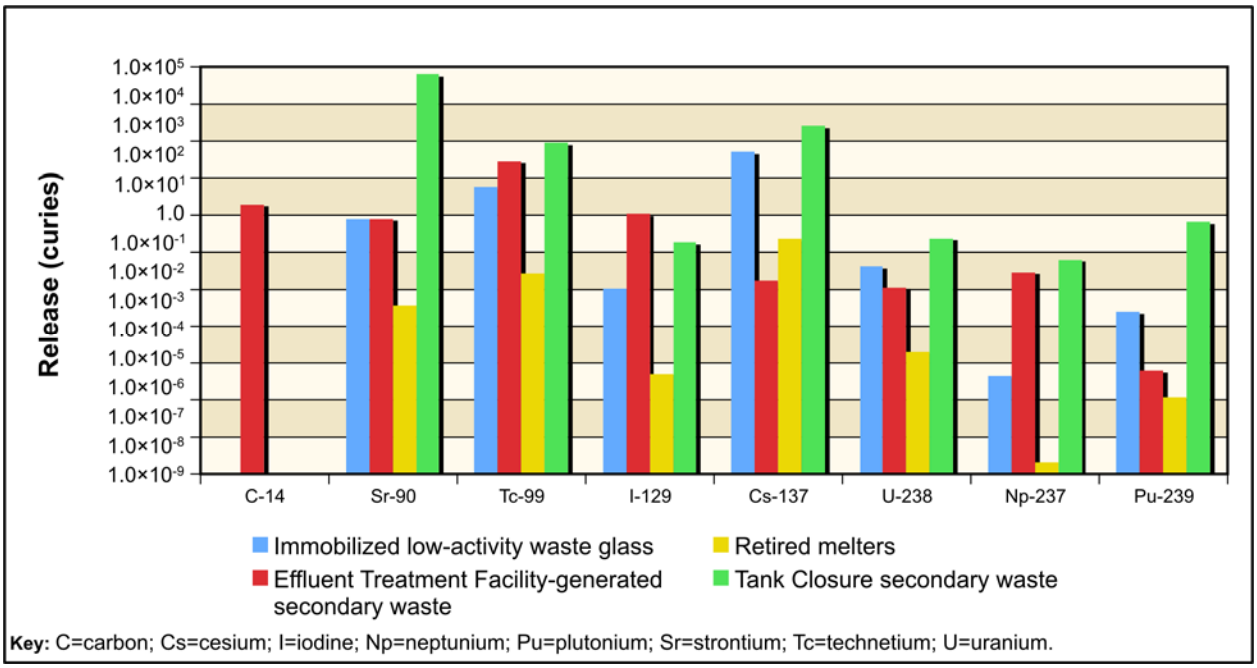


Figure M–88. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

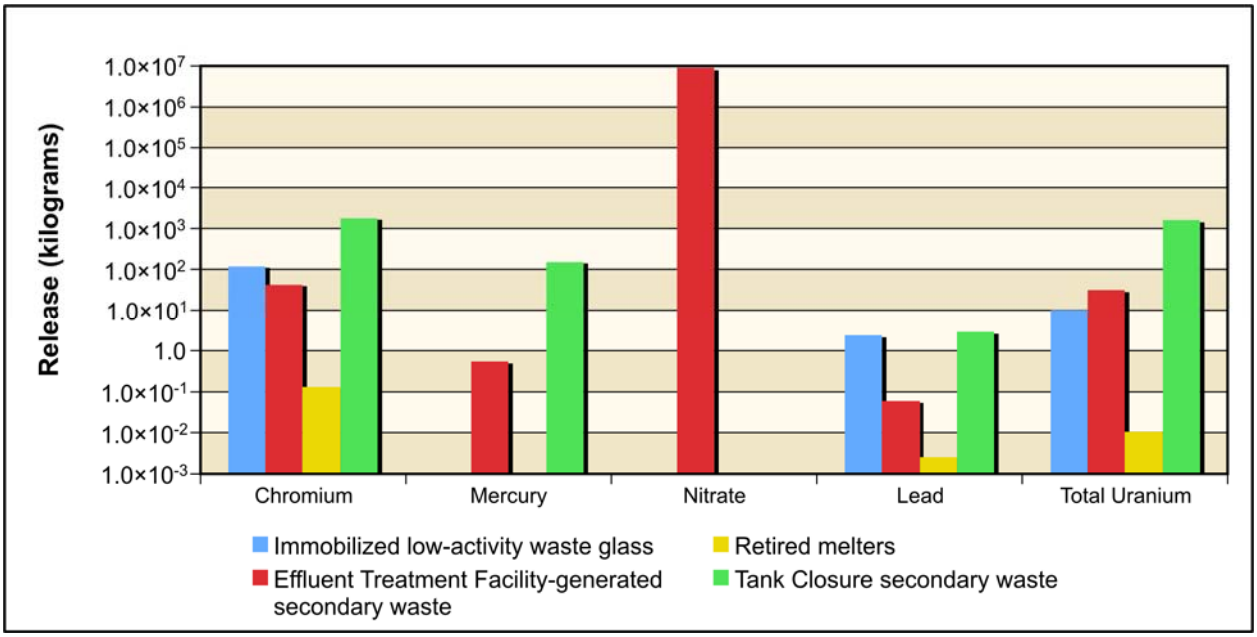


Figure M–89. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.9 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 2, Subgroup 2-B

Disposal Group 2, Subgroup 2-B, addresses the waste resulting from Tank Closure Alternative 6B, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6B, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base and Option Cases, are indicated in Figures M–90 through M–93.

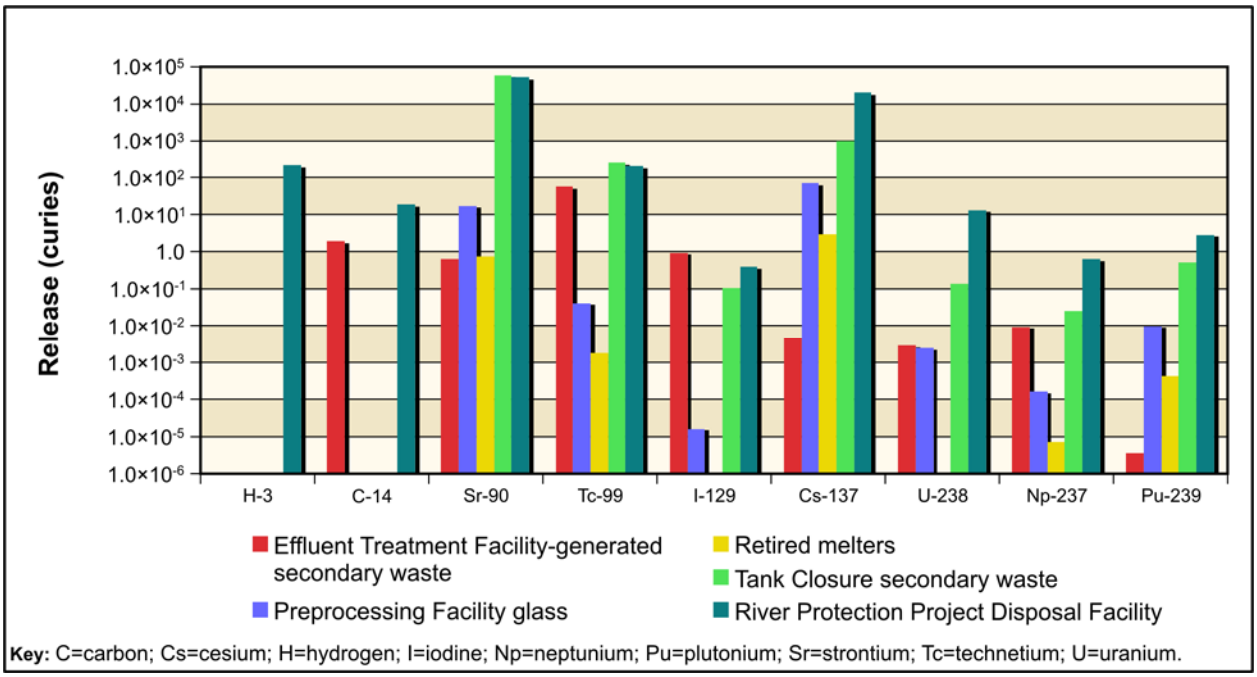


Figure M–90. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base Case, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

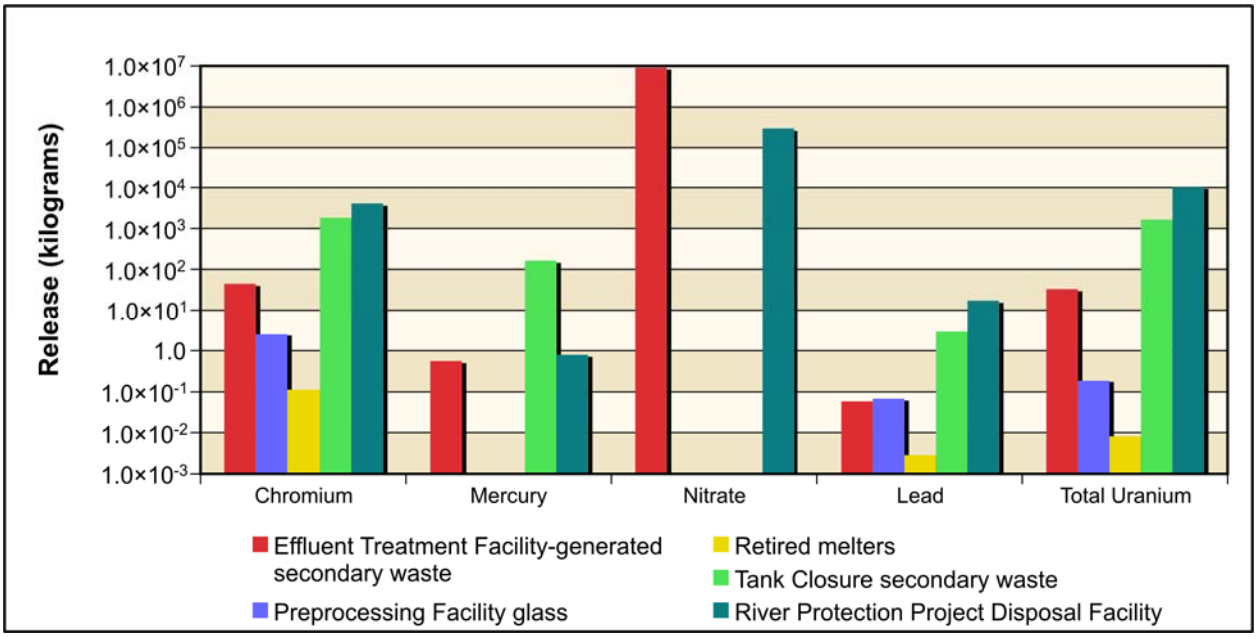


Figure M–91. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base Case, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

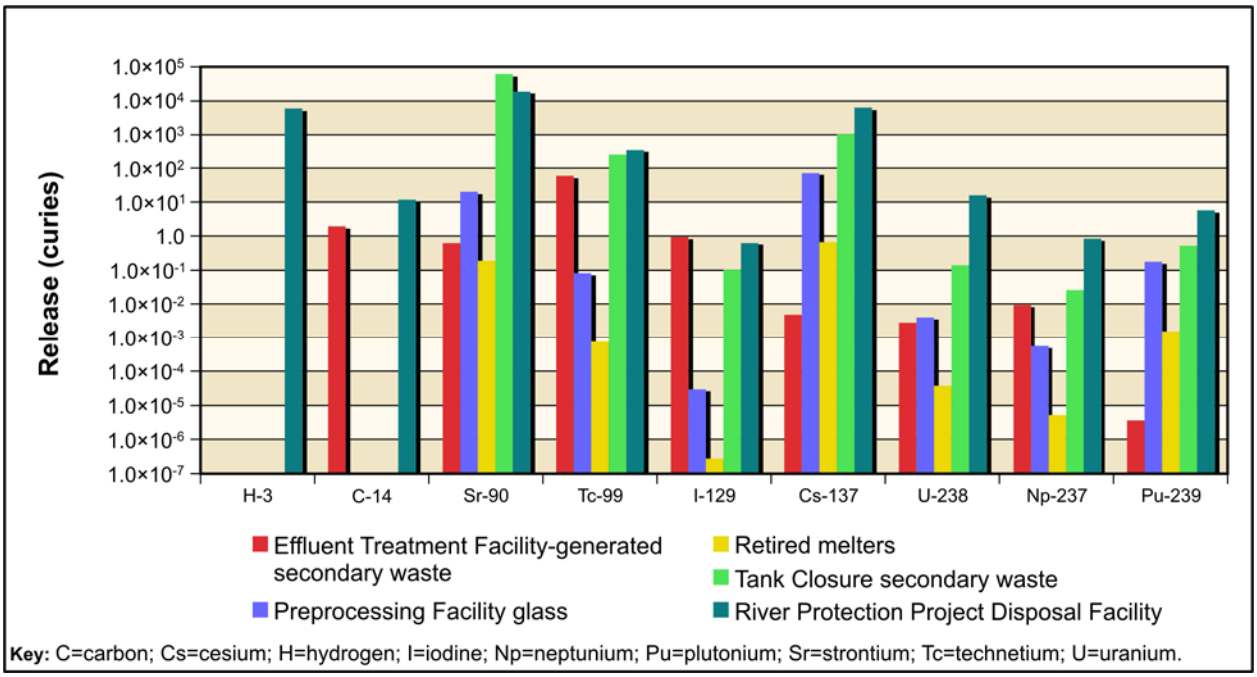


Figure M–92. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Option Case, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

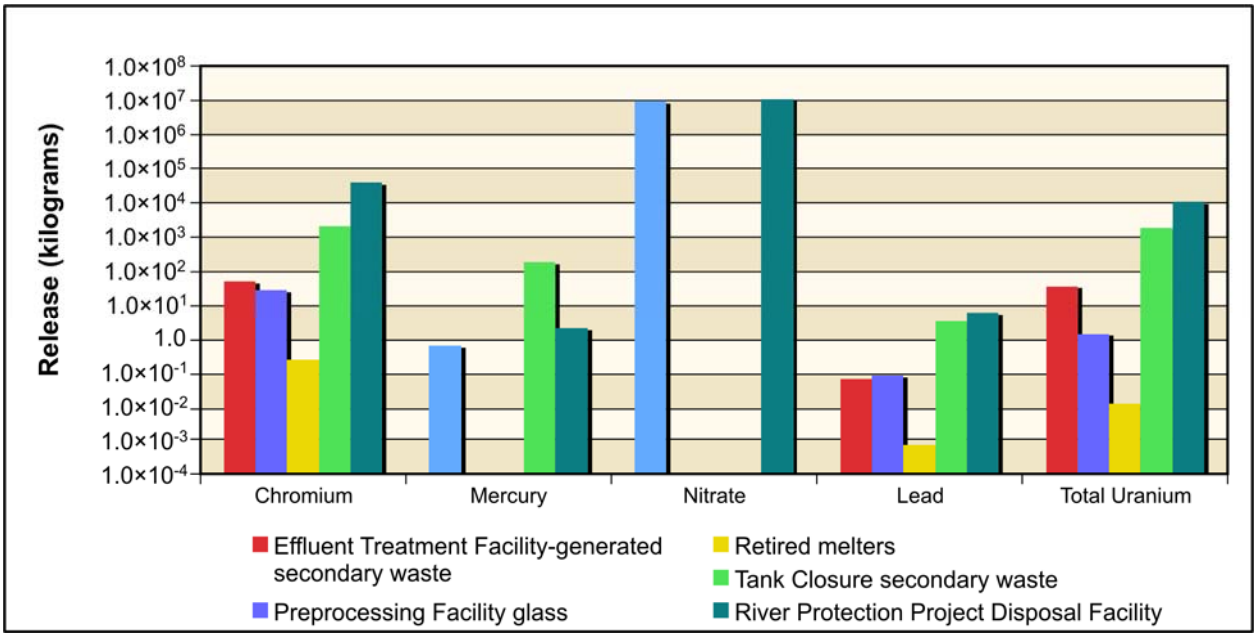


Figure M–93. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Option Case, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.10 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 3

Disposal Group 3 addresses the waste resulting from Tank Closure Alternative 6A, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6A, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 3, Base and Option Cases, are indicated in Figures M–94 through M–97.

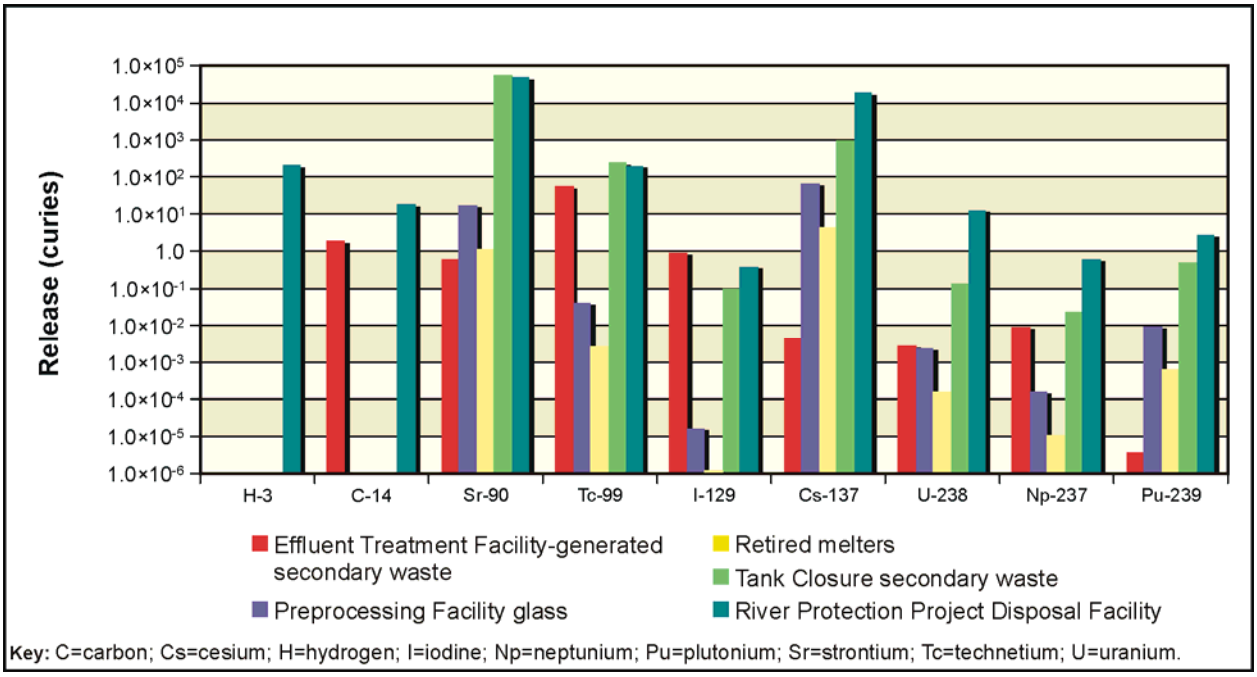


Figure M–94. Waste Management Alternative 3, Disposal Group 3, Base Case, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

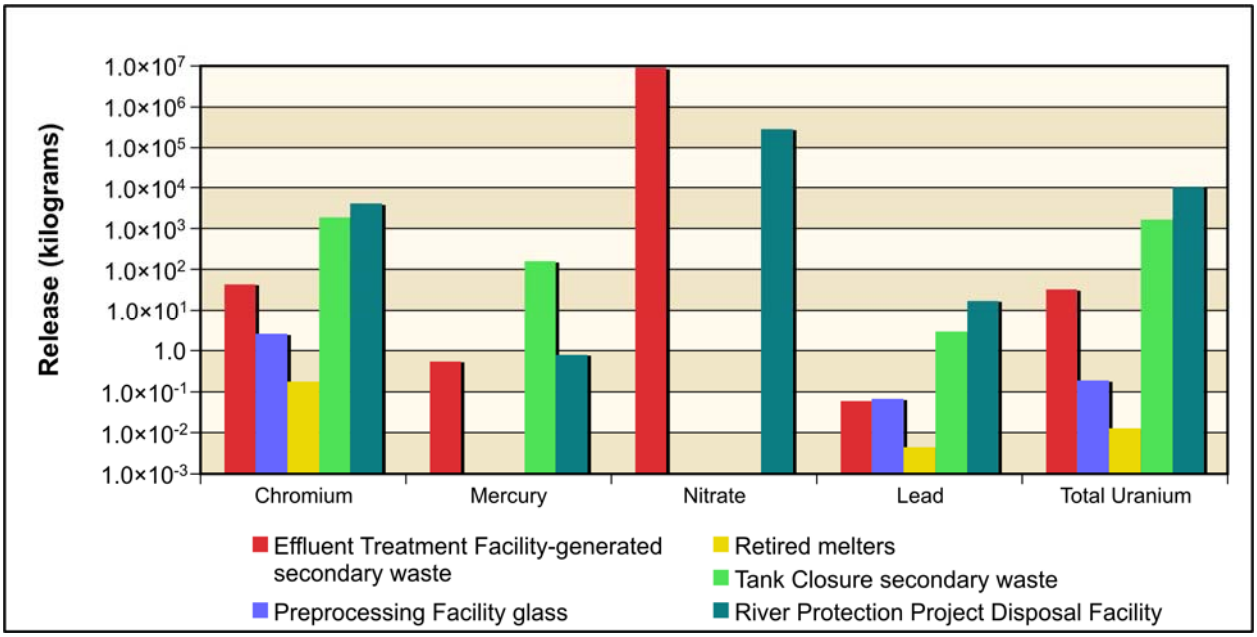


Figure M–95. Waste Management Alternative 3, Disposal Group 3, Base Case, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

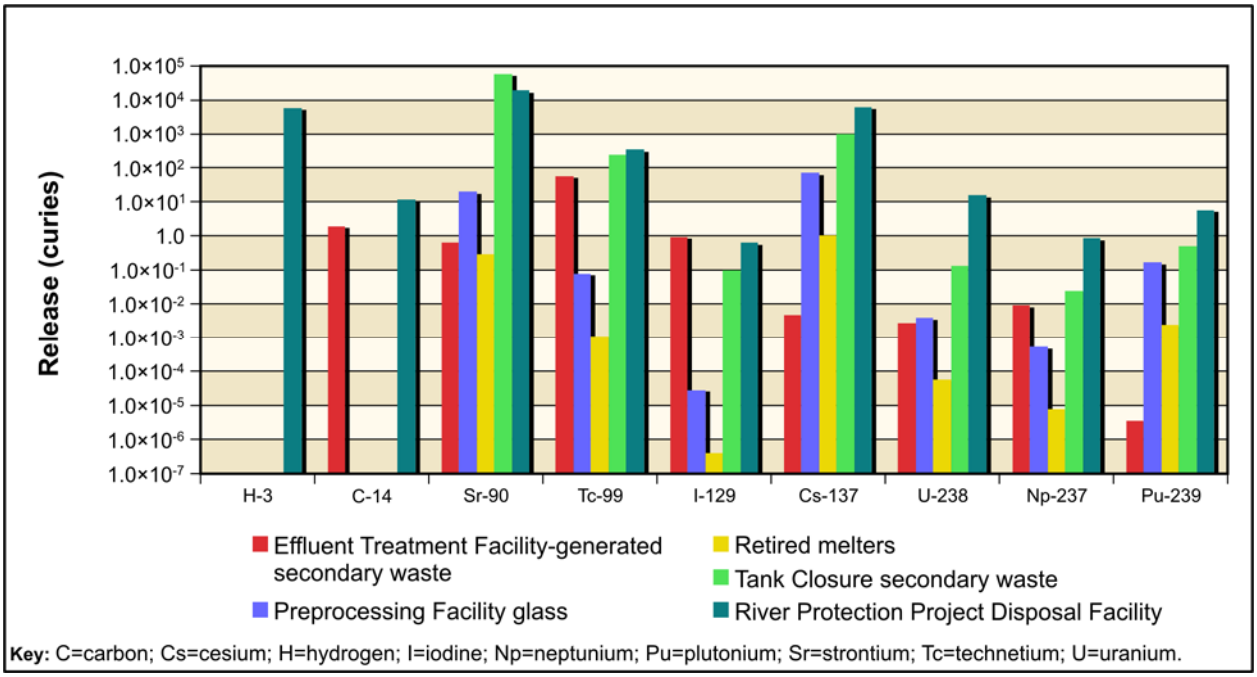


Figure M–96. Waste Management Alternative 3, Disposal Group 3, Option Case, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

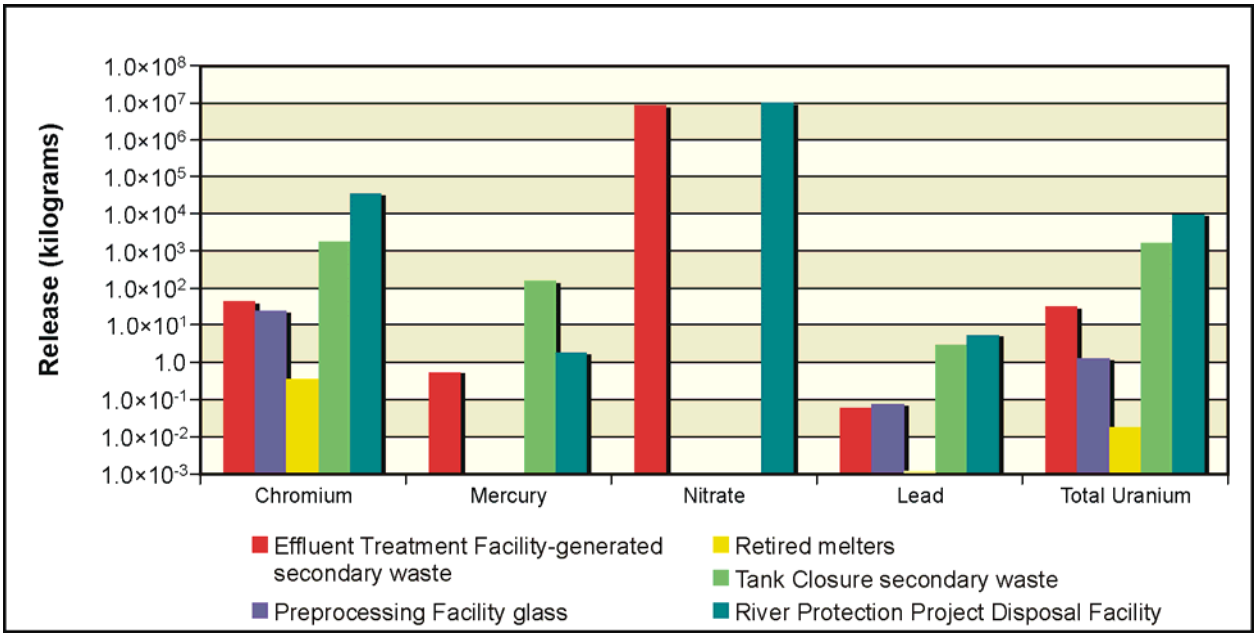


Figure M–97. Waste Management Alternative 3, Disposal Group 3, Option Case, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.5 SENSITIVITY ANALYSIS

Because of the long-term nature of processes expected to occur at Hanford, mathematical models were developed to estimate the rate of release of constituents to the vadose zone. Estimates thus depend on the description of the release incorporated into the model and on values of parameters that quantify rates of physical and chemical processes comprising the model. The objective of this section is to investigate the sensitivity of the estimates of rate of release to the vadose zone to elements of the model concepts and to values of parameters used in the models. Three cases are considered: discharge of liquid and solute representing a past leak at a tank farm, leaching from supplemental waste forms in the 200-East Area, and diffusive release from a grout waste form. The three cases illustrate the range of sensitivities for liquid and solid sources.

M.5.1 Aqueous Volumetric Release

During tank farm operations, aqueous liquids and solutes were discharged to the vadose zone in uncontrolled leakage events. The magnitude, duration, and timing of the leaks and the spatial distribution of recharge at the tank farms are not well characterized. Studies have determined that the volume of leaks may be as large as 400 cubic meters (100,000 thousand gallons) (Hanlon 2003) and that recharge at the tank farms may be high relative to Hanford background conditions (DOE 2005). To investigate the sensitivity of potential impacts on conditions affecting an aqueous discharge at a tank farm, two cases were evaluated. In the first case, an isolated tank in the center of a tank farm was surrounded by an area of elevated recharge, and the release duration and timing were varied. In the second case, the area of an isolated tank was subject to excess recharge while the surrounding area experienced recharge at a normal background rate, and the leak duration and timing were varied. A plan view of the configuration is presented in Figure M–98. The inner area representing the tank is dimension 20 meters (66 feet) in both horizontal directions. In the first case, the dashed rectangle representing the tank farm area experienced recharge at 100 millimeters (4 inches) per year and the balance of the study area experienced recharge at 3.5 millimeters (0.012 inches) per year. In the second case, only the area of the source experienced recharge at 100 millimeters (4 inches) per year and the balance of the study area experienced recharge at 3.5 millimeters (0.012 inches) per year. The initial moisture profile was established as the steady state

condition at a recharge rate of 3.5 millimeters (0.012 inches) per year, and elevated recharge is assumed to begin at the start time of tank farm operations. In both cases, the site geology corresponded to 200-West Area conditions with Hanford Gravel, Hanford Sand, Plio-Pleistocene Silt, and Ringold Gravel layered from the ground surface downward to the water table at a depth of 70 meters (330 feet).

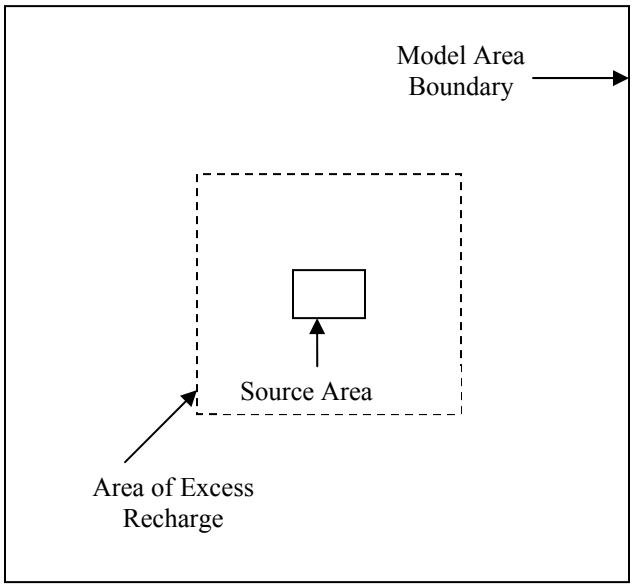


Figure M–98. Plan View of Aqueous Discharge Study Area

M.5.1.1 Extended Area of Elevated Recharge

In this first case, elevated recharge is assumed to occur over the area of a tank farm, approximately 10,000 square meters (110,000 square feet), and the leak duration and timing were varied. For a leak beginning at the start time of tank operations, a solute flux at the water table for leaks of duration of 1 year, 1 month, 1 week, and 1 day are presented in Figure M–99. Releases of relatively short duration are considered because these have the greatest potential to produce high flux of solute at the water table. Results show only a small dependence of solute flux at the water table on duration of release. For a 1-year release duration, solute flux at the water table for releases beginning at the start of tank farm operations and at 15 and 30 years after start are presented in Figure M–100. Results indicate that the transition from background to elevated recharge moisture conditions did not have a significant effect on the time profile of solute flux. The magnitude of peak solute flux varied by approximately 5 percent as release timing changed from start of operations to 30 years after start of operations. Results reflect the delay in arrival due to the delay in beginning of release, but the interval of time from release to peak dose decreased by approximately 1 percent as time of release changed from start of operations to 30 years after start of operations.

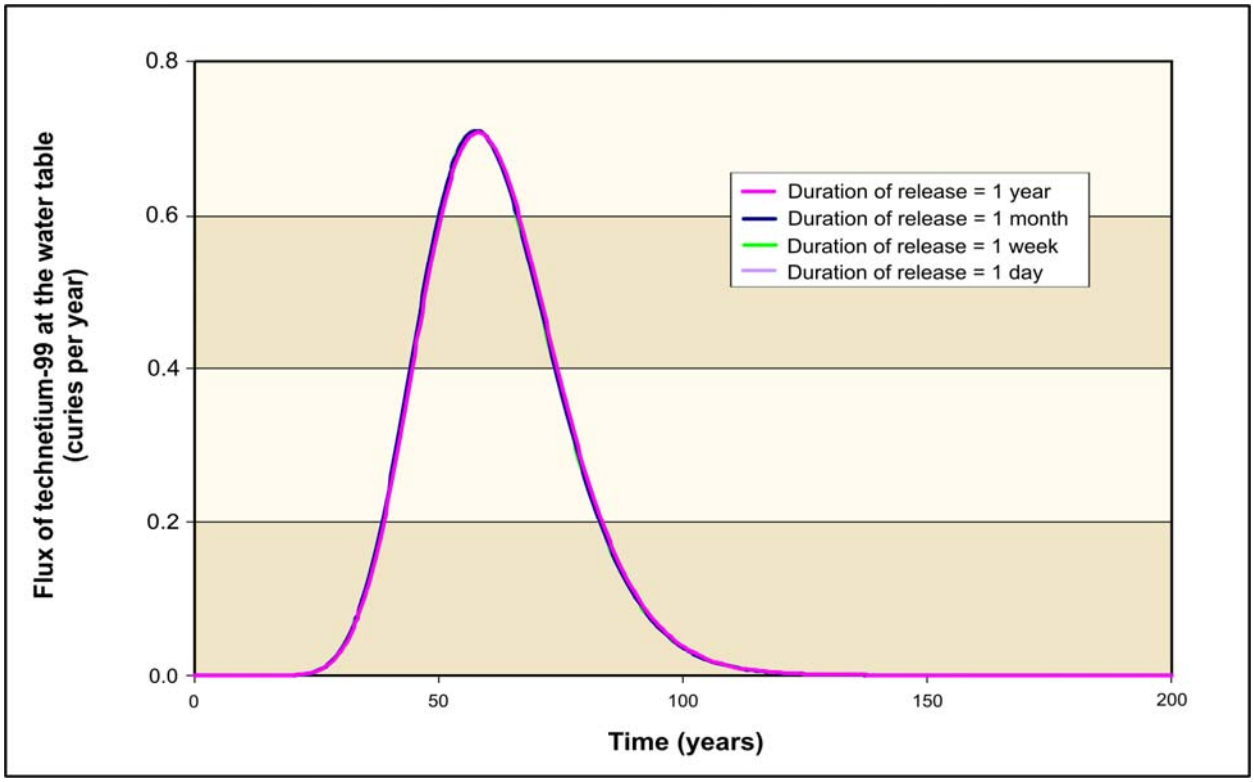


Figure M–99. Variation of Solute Flux at the Water Table with Release Duration for Extended Area of Elevated Recharge

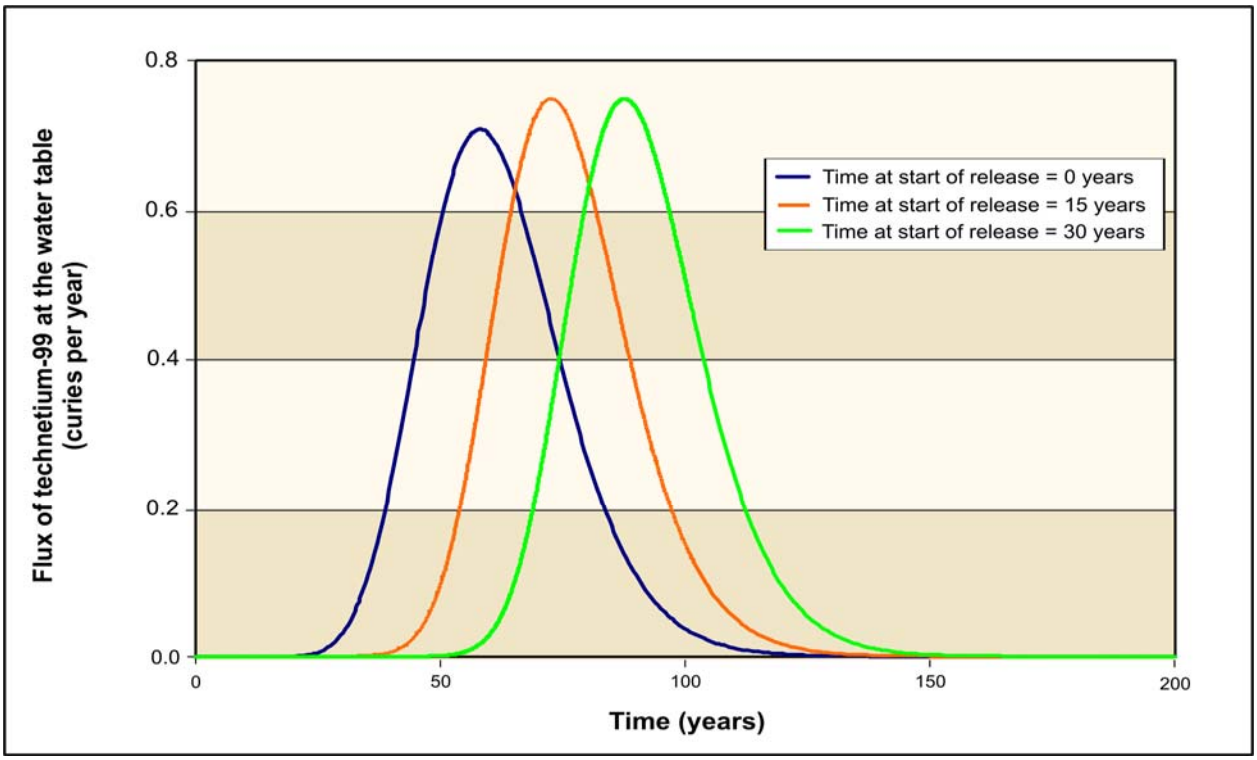


Figure M–100. Variation of Solute Flux at the Water Table with Release Timing for Extended Area of Elevated Recharge

M.5.1.2 Local Area of Elevated Recharge

In this second case, elevated recharge is assumed to occur only over the area of a tank, approximately 400 square meters (4300 square feet), and the leak duration and timing were varied. For a leak beginning at the start time of tank operations, solute flux at the water table for leaks of duration of 1 year, 1 month, 1 week, and 1 day are presented in Figure M–101. Results show only a small dependence of solute flux at the water table on duration of release. For a 1-year release duration, solute flux at the water table for releases beginning at the start of tank farm operations and at 15 and 30 years after start are presented in Figure M–102. Results indicate that the transition from background to elevated recharge moisture conditions did not have a significant effect on the time profile of solute flux. The magnitude of peak solute flux varied by approximately 2 percent as release timing changed from start of operations to 30 years after start of operations. Results reflect the delay in arrival due to the delay in beginning of release, but the interval of time from release to peak dose remained approximately constant as time of release changed from start of operations to 30 years after start of operations.

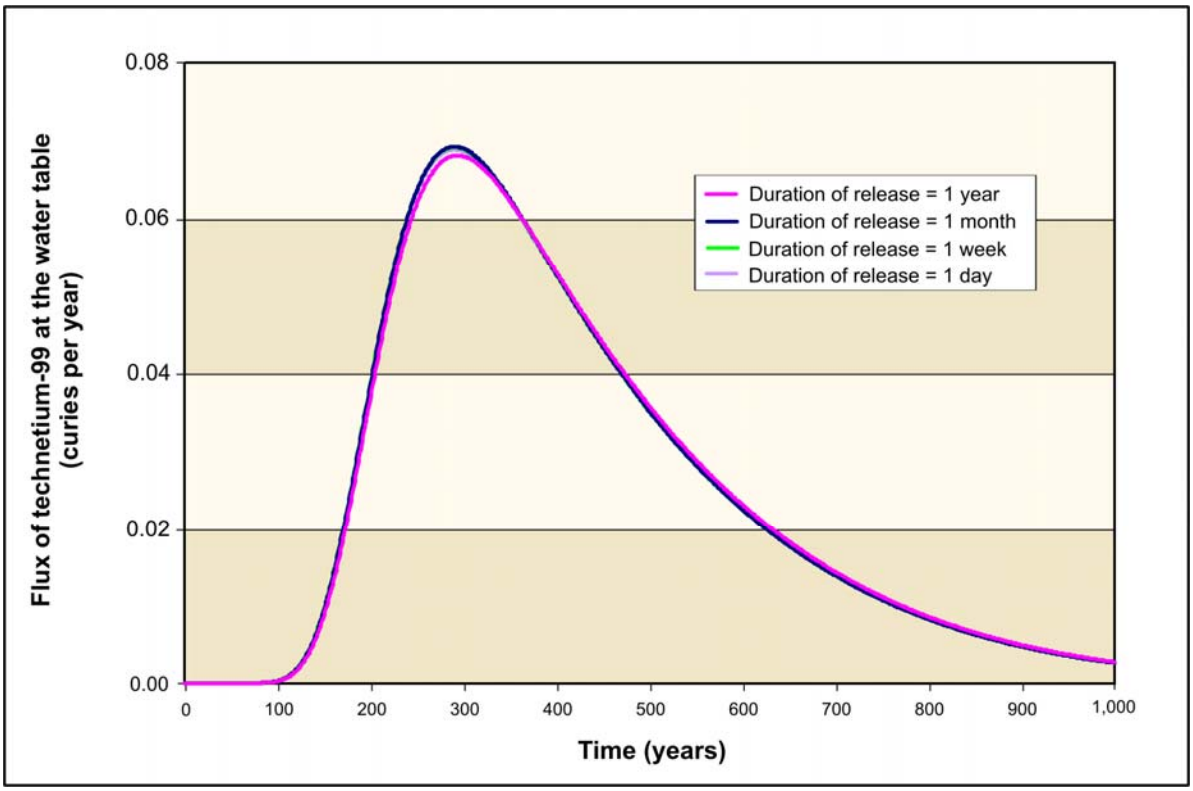


Figure M–101. Variation of Solute Flux at the Water Table with Release Duration for Local Area of Elevated Recharge

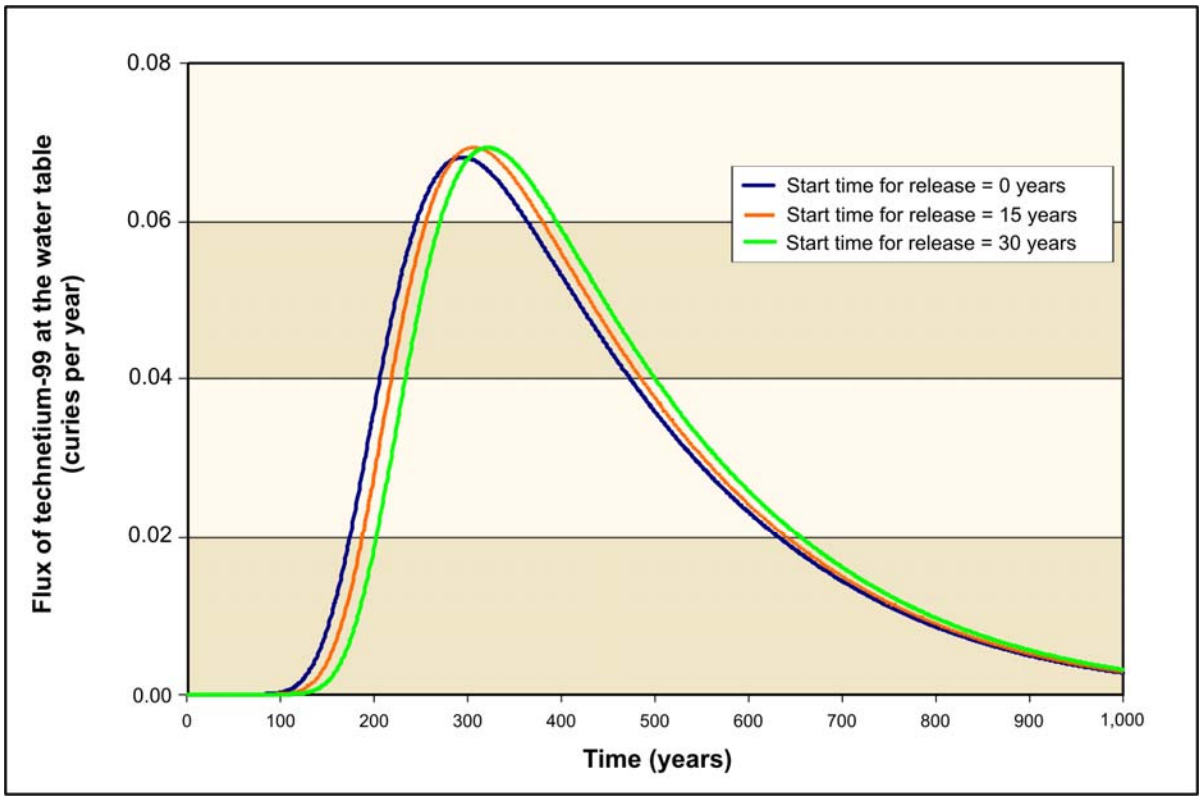


Figure M–102. Variation of Solute Flux at the Water Table with Release Timing for Local Area of Elevated Recharge

M.5.1.3 Conclusions

For cases of both extended and local areas of elevated recharge, solute flux at the water table showed low sensitivity to change in release duration and timing. Results show sensitivity to moisture conditions as the average travel time for the case of extended area of elevated recharge was approximately one-quarter the average travel time for the case of local area of elevated recharge.

M.5.2 Leaching from Supplemental Waste Forms

Activities under consideration for this *TC & WM EIS* include solidification of hazardous constituents currently stored in below ground tanks in the 200-East and 200-West Areas. The primary waste form proposed is ILAW glass. Three additional waste forms under consideration to supplement management capacity for tank constituents are: bulk vitrification glass, cast stone, and steam reforming solids. Analysis completed for Tank Closure Alternatives 3A, 3B, and 3C provides a basis for comparative evaluation of these three waste forms. Additional details on the nature of these waste forms are provided in Appendix D of this EIS, while estimates of the inventory of technetium-99 and iodine-129 for the set of waste forms for the three variants of Tank Closure Alternative 3 are summarized in Table M–17. The balance of this section presents details on the sensitivity of release rate estimates of two select radionuclides to the vadose zone to change in the type of waste form. The recharge rate selected as the basis for estimating release rates was 0.9 millimeters (0.035 inches) per year, a value recommended for the proposed IDF-East (DOE 2005).

Table M–17. Tank Closure Alternatives 3A, 3B, and 3C Summary of Waste Form Inventories of Technetium-99 and Iodine-129

Waste Form	Technetium-99 (curies)			Iodine-129 (curies)		
	Alternative 3A	Alternative 3B	Alternative 3C	Alternative 3A	Alternative 3B	Alternative 3C
Immobilized high-level radioactive waste	150	19,600	150	0	0	0
ILAW glass	8,440	84	8,440	2.8	2.8	2.8
Bulk vitrification glass	20,600[a]	N/A[b]	N/A[b]	6.8	N/A[b]	N/A[b]
Cast stone	N/A[b]	9,540	N/A[b]	N/A[b]	33.8	N/A[b]
Steam reforming solids	N/A[b]	N/A[b]	20,600	N/A[b]	N/A[b]	6.8
ETF secondary waste	50	60	46	36.9	9.9	36.9

[a] The inventory of technetium-99 in the castable refractory block is 1,340 curies with the balance of the technetium-99 in intact bulk vitrification glass.

[b] Waste form not used in this alternative.

Key: ETF=Effluent Treatment Facility; ILAW=immobilized low-activity waste; N/A= not applicable.

M.5.2.1 Tank Closure Alternative 3A

For Tank Closure Alternative 3A, the inventory of technetium-99 is largely divided between ILAW glass and bulk vitrification glass while the inventory of iodine-129 is divided between ILAW glass, bulk vitrification glass and ETF secondary waste (a grout waste form). Release rate estimates of technetium-99 and iodine-129 for this alternative are presented in Figures M–103 and M–104, respectively. Low rates of release are predicted for the intact glass of the ILAW and bulk vitrification glass waste forms. However, the portion of technetium-99 transferred to castable refractory block in the bulk vitrification container is projected to release at a much higher rate upon placement in the vadose zone. The peak in the release rate for technetium-99 from castable refractory block reflects the increase in infiltration that is specified to occur at the end of the design life of the engineered barrier. For iodine-129, the glass waste forms release at very low rates, while the ETF secondary waste releases iodine at a higher (but still low) rate.

M.5.2.2 Tank Closure Alternative 3B

For Tank Closure Alternative 3B, the inventory of technetium-99 is largely divided between immobilized high level radioactive waste glass and cast stone while the inventory of iodine-129 is divided between ILAW glass, cast stone, and ETF secondary waste. Release rate estimates of technetium-99 and iodine-129 for this alternative are presented in Figures M–105 and M-106, respectively. The small amount of technetium-99 present in the ILAW glass is estimated to release at a low rate, while the cast stone is projected to release technetium-99 at a higher rate. The entire inventory of technetium-99 in the cast stone waste form is released over a period of approximately 9,600 years. The smaller inventory of technetium-99 (60 curies) in the ETF secondary waste is released over a period of approximately 3,000 years. For iodine-129, the combined rate of release from cast stone and ETF secondary waste is comparable to that of ETF secondary waste with comparable inventory under Tank Closure Alternative 3A.

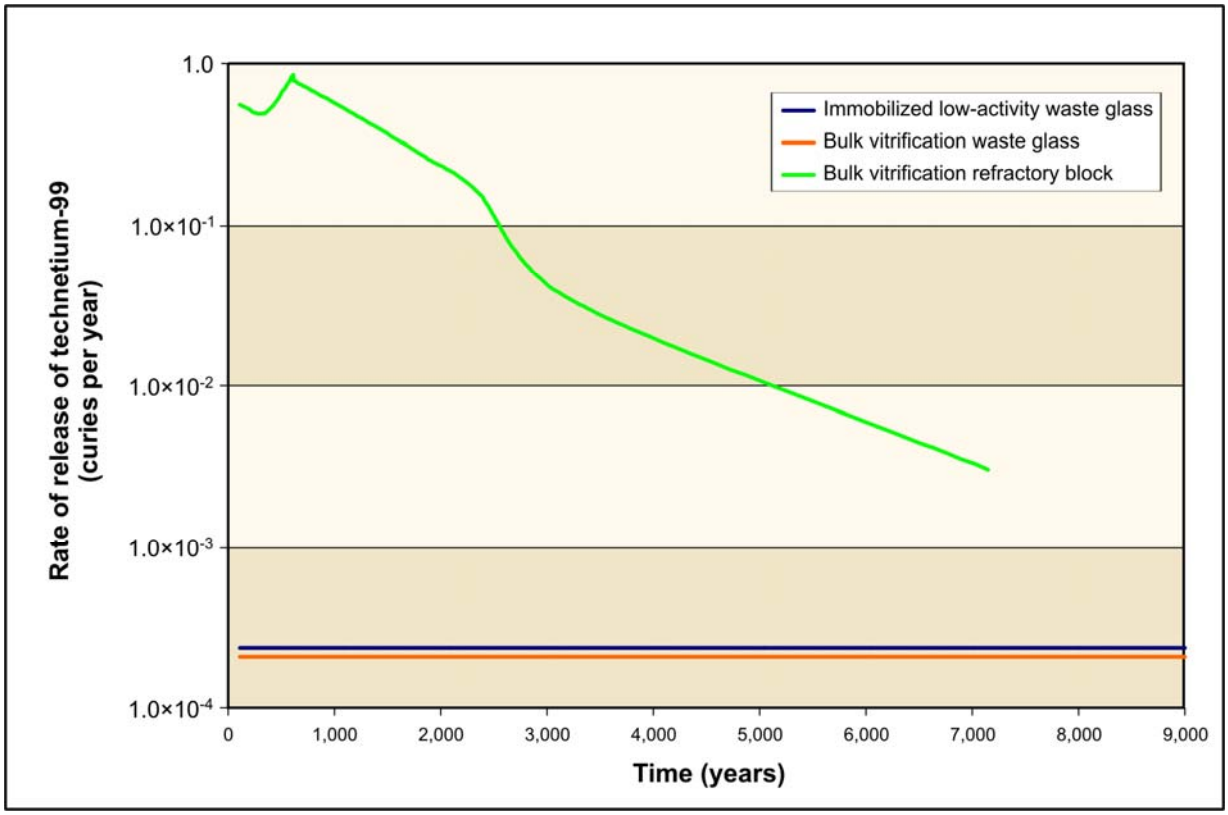


Figure M–103. Tank Closure Alternative 3A Waste Form Release Rates of Technetium-99

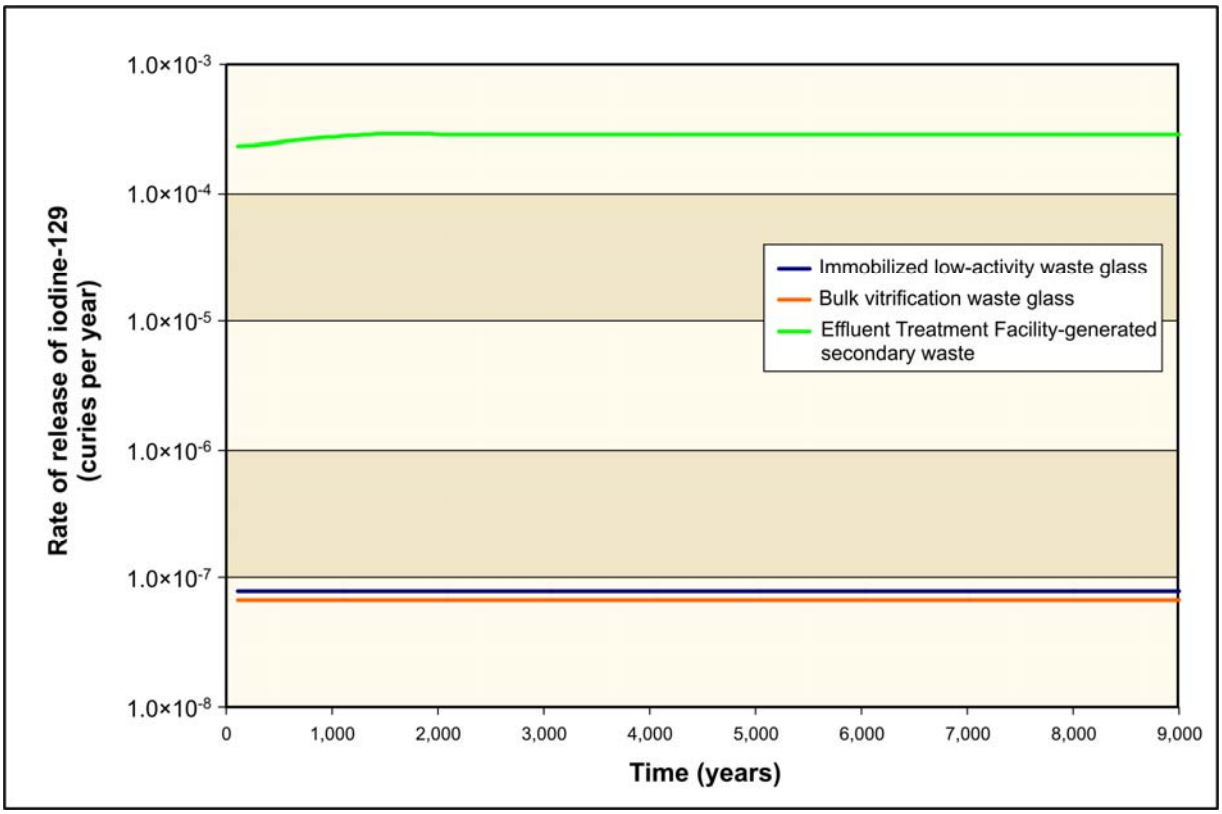


Figure M–104. Tank Closure Alternative 3A Waste Form Release Rates of Iodine-129

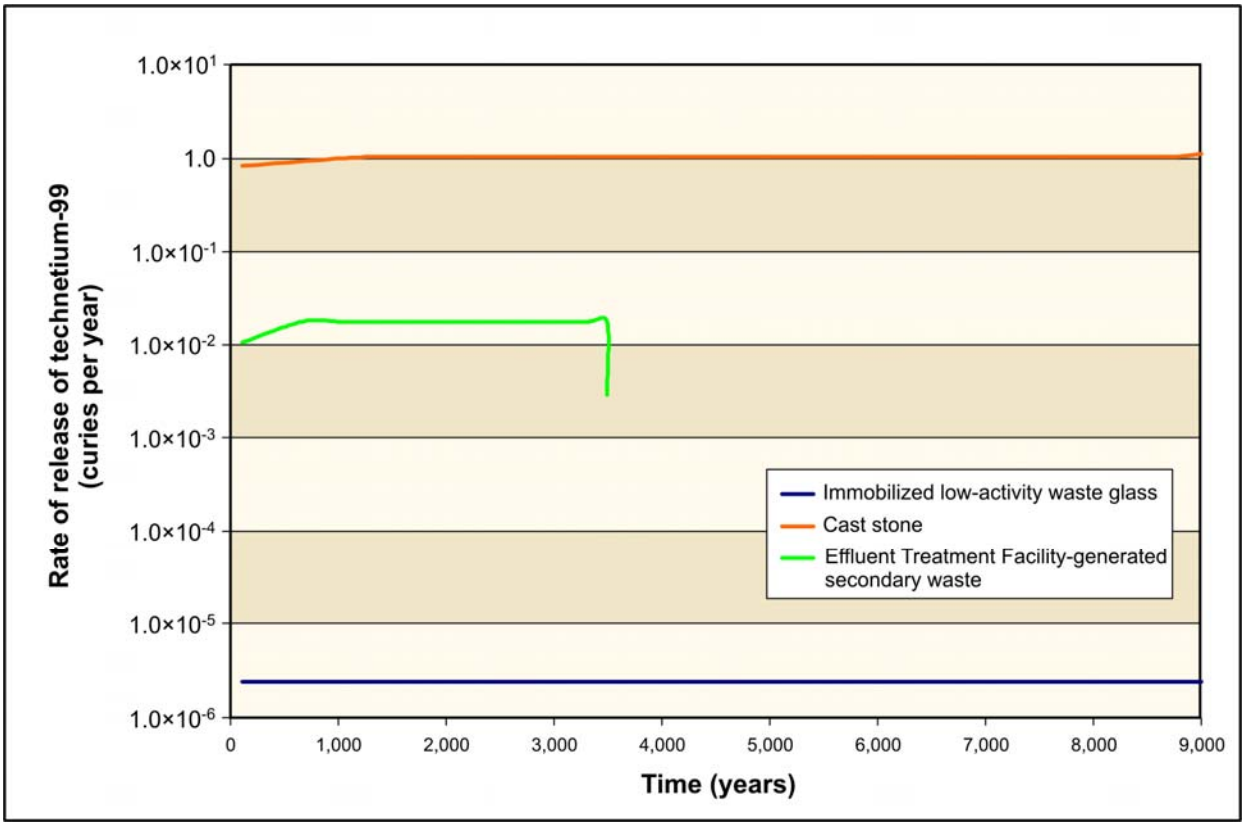


Figure M–105. Tank Closure Alternative 3B Waste Form Release Rates of Technetium-99

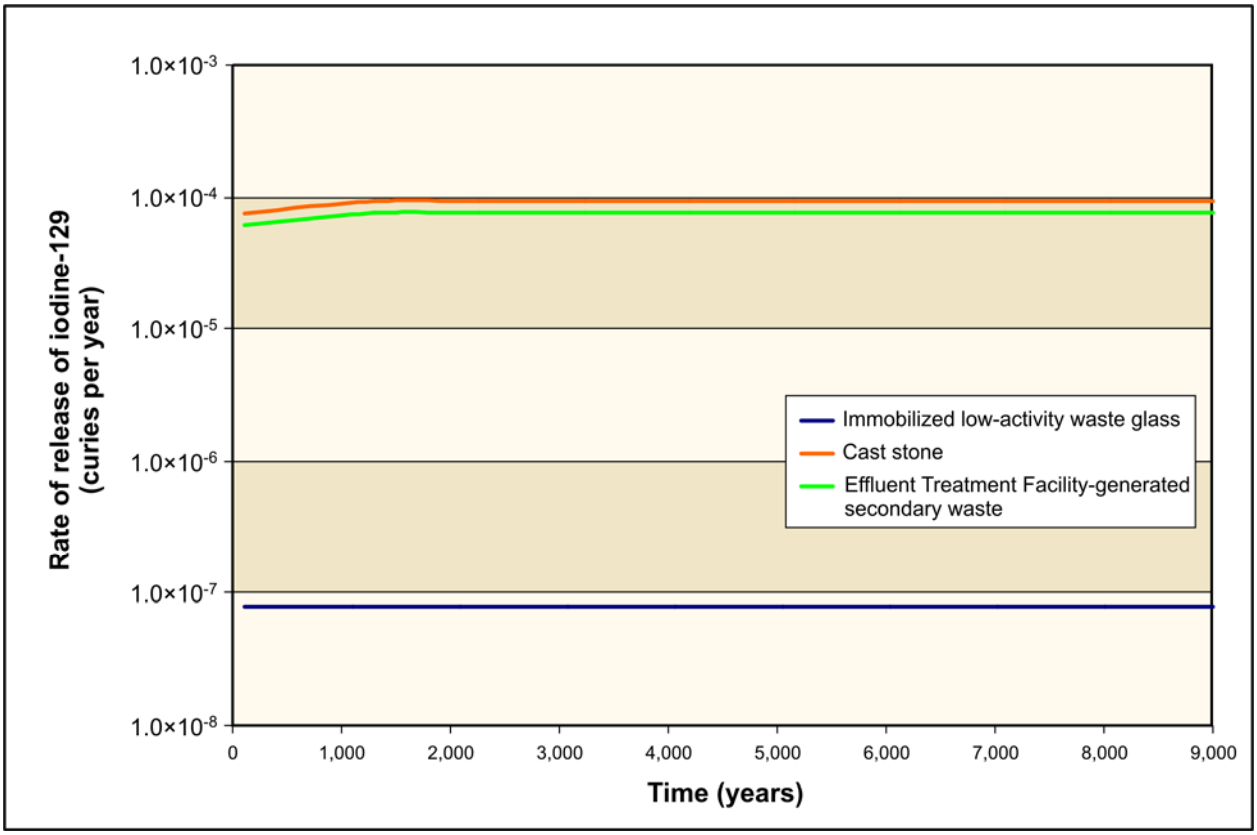


Figure M–106. Tank Closure Alternative 3B Waste Form Release Rates of Iodine-129

M.5.2.3 Tank Closure Alternative 3C

For Tank Closure Alternative 3C, the inventory of technetium-99 is largely divided between ILAW glass and steam reforming solids, while the inventory of iodine-129 is divided between ILAW glass, steam reforming solids, and ETF secondary waste. Release rate estimates of technetium-99 and iodine-129 for this alternative are presented in Figures M–107 and M–108, respectively. The estimated rate of release of both technetium-99 and iodine -129 is higher for steam reforming solids than for the ILAW glass waste form. The entire inventories would be released over a period of approximately 2,000 years.

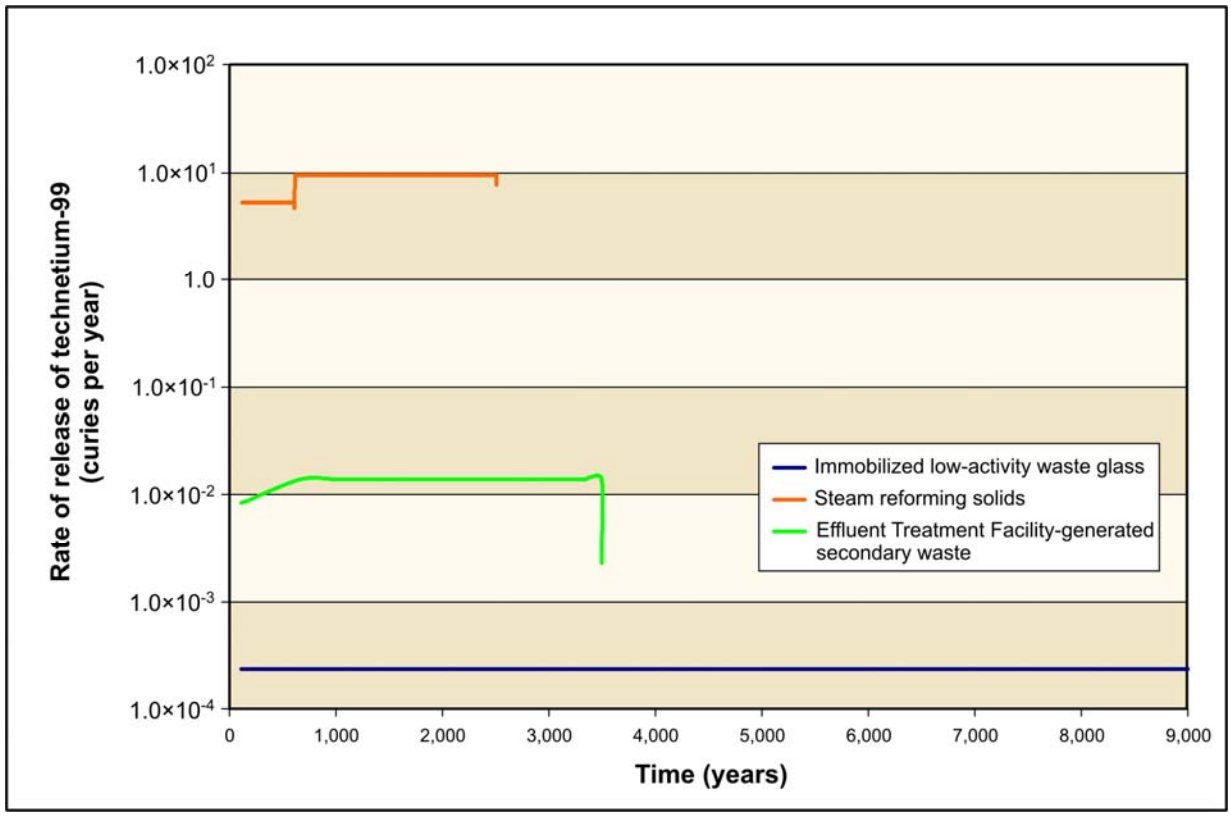


Figure M–107. Tank Closure Alternative 3C Waste Form Release Rates of Technetium-99

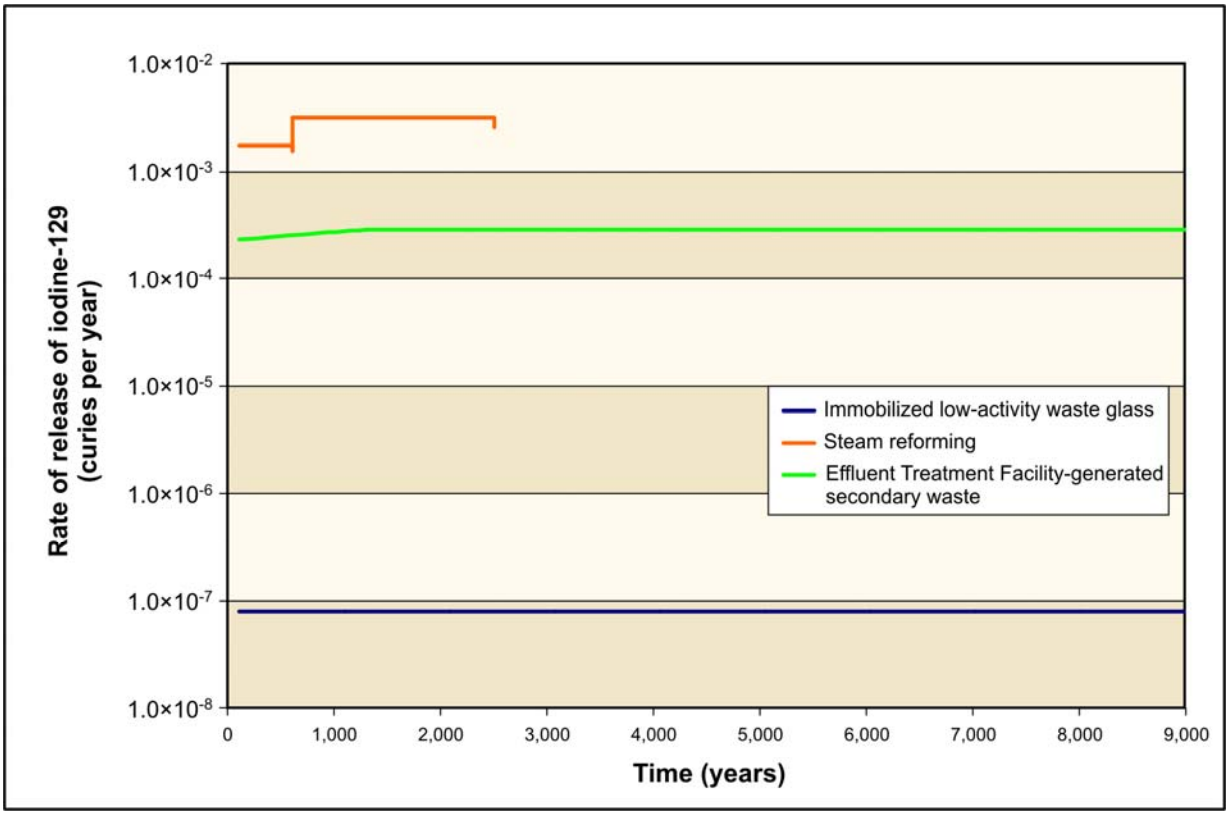


Figure M–108. Tank Closure Alternative 3C Waste Form Release Rates of Iodine-129

M.5.2.4 Conclusions

Cumulative releases of technetium-99 and iodine-129 from the combined waste forms for Tank Closure Alternatives 3A, 3B, and 3C are presented in Figure M–109 and M–110, respectively. For both technetium-99 and iodine-129, estimates of release from steam reforming solids are higher than those for the ILAW glass, bulk vitrification glass, and cast stone waste forms. This is due to use of a conservative, reactant limited-release model for the steam reforming solids. For technetium-99 and Tank Closure Alternative 3A, the majority of release is due to the castable refractory block portion of the bulk vitrification inventory, and that entire inventory is released in approximately 2,000 years. For technetium-99, cumulative release from cast stone under Tank Closure Alternative 3B is higher than for bulk vitrification glass and castable refractory block under Alternative 3A due in part to a larger initial inventory. For iodine-129, estimates of release from ILAW glass and bulk vitrification glass are comparable, although that of bulk vitrification glass is slightly lower due to smaller surface area per unit mass of the waste form.

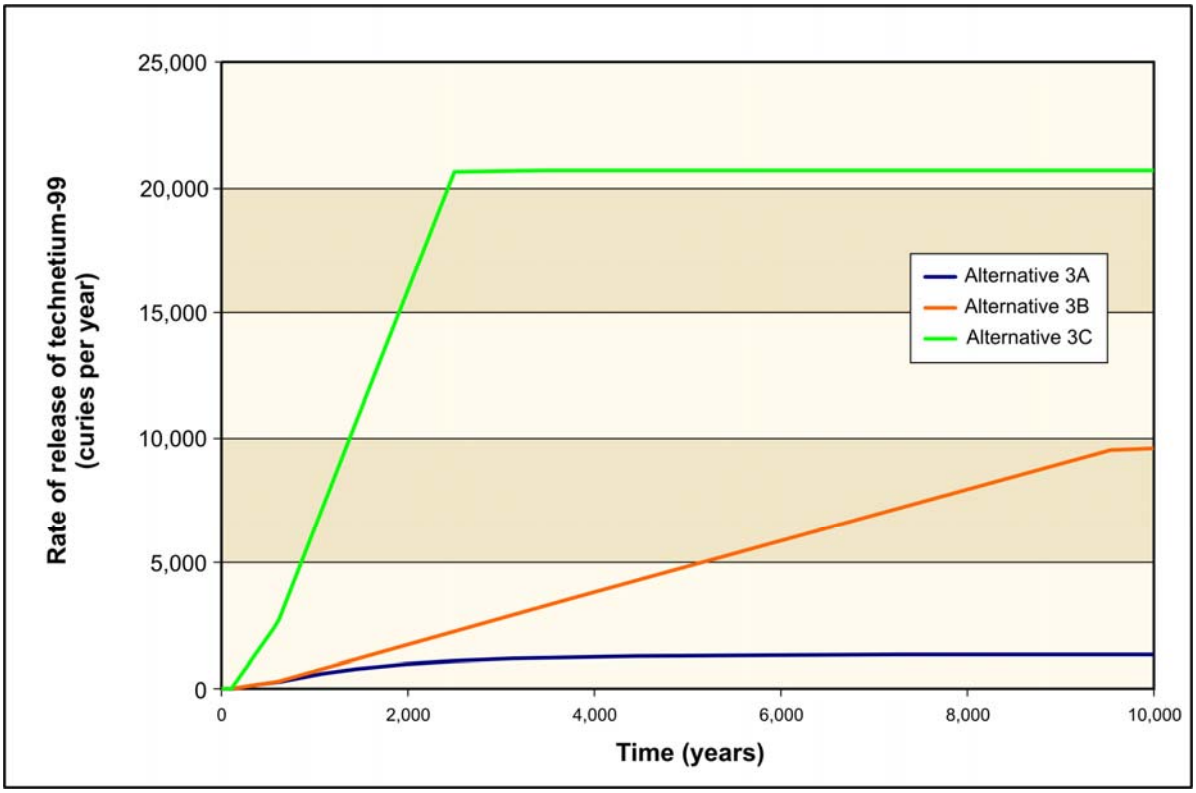


Figure M–109. Tank Closure Alternatives 3A, 3B, and 3C Waste Form Combined Release Rates of Technetium-99

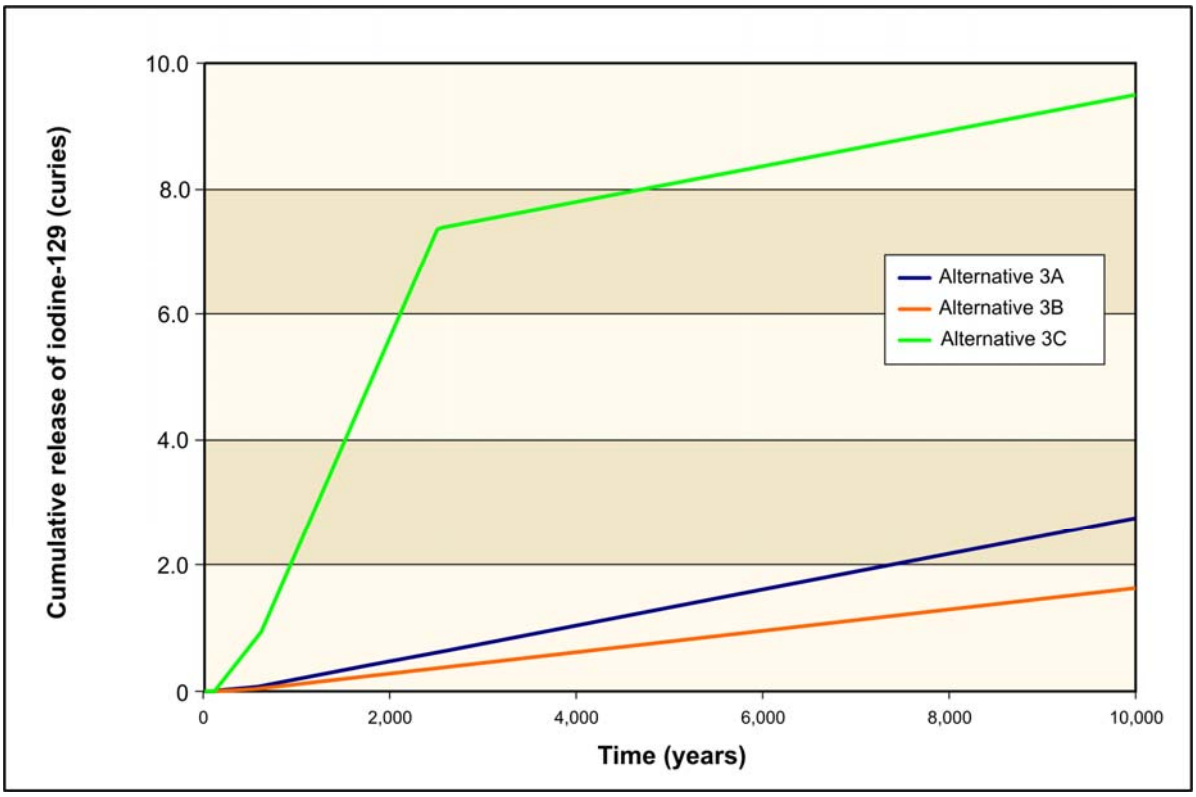


Figure M–110. Tank Closure Alternatives 3A, 3B, and 3C Waste Form Combined Release Rates of Iodine-129

M.5.3 Rate of Recharge and Diffusion Release

Grouted waste forms are proposed for both primary and secondary waste categories for Tank Closure and Waste Management alternatives. For these waste forms and the low rates of recharge projected for the waste disposal locations, release rate by the diffusion mechanism is greater than that by the convective mechanism. Also, for the diffusive model described in Section M.2.2.4, the release rate from the waste package would be limited by the accumulation of the released constituent in the vicinity of the waste form. This section investigates the dependence of the release rate to the vadose zone underlying the waste packages on the recharge rate in the vicinity of the waste form. In this example, calculation, an inventory of 9,500 curies of technetium-99 is encapsulated in 233,000 cubic meters (8,230,000 cubic feet) of grout. Stacks of packages 5.3 meters (17.4 feet) high with a package radius of 1.55 meters (5.1 feet) are placed in a rectangular array. The constituent is released by diffusion into the vadose zone adjacent to the packages and transported downward in the convective flow due to recharge. The release rates to the underlying vadose zone for varying recharge rates are presented in Figure M–111. In the limit of very high values of recharge, the release rate would be independent of the recharge rate and decrease in inverse proportion to the square root of time. The constant release rate projected for recharge rates observed at Hanford (see Figure M–105) indicates that the accumulation of the released constituent in the vadose zone adjacent to the packages limits the release rate. For the conditions adopted for this analysis, the entire inventory of technetium-99 is released during the period analyzed with the duration of time required for release increasing in proportion to the inverse of the recharge rate.

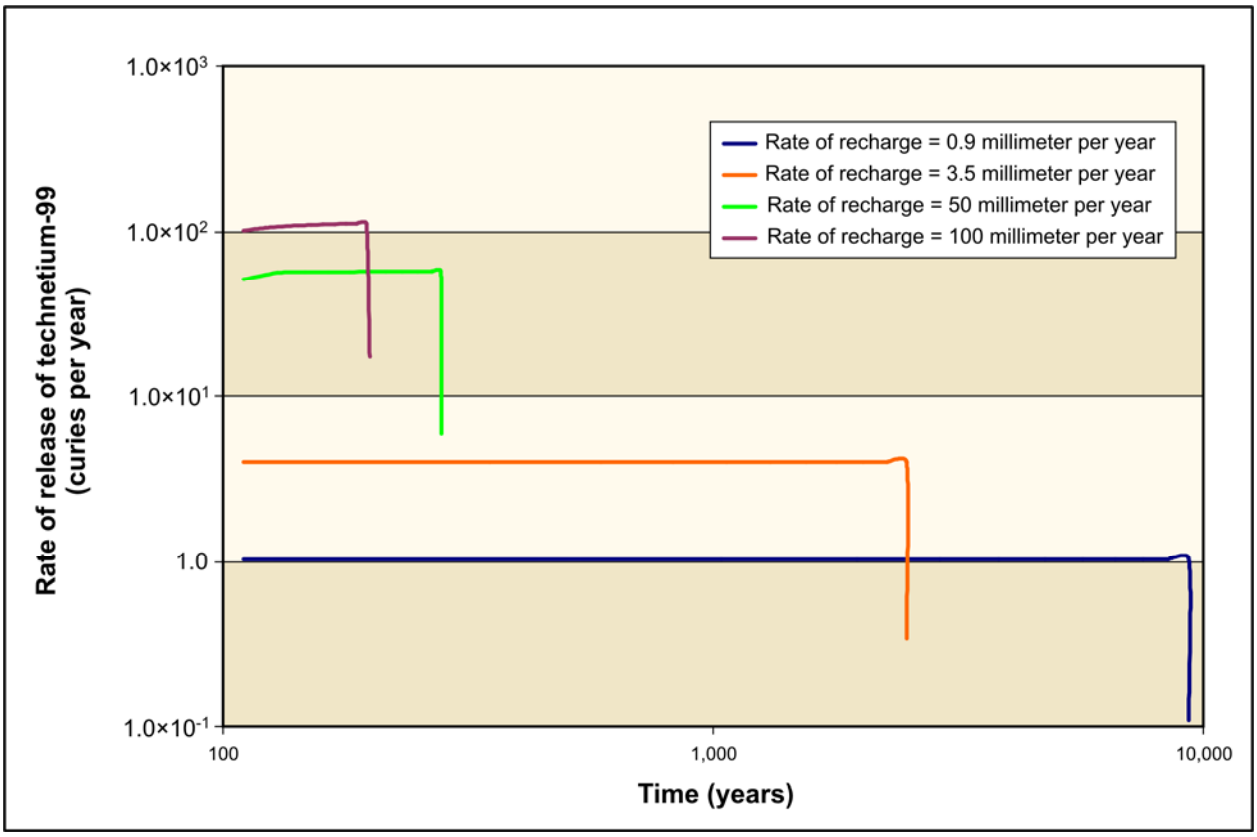


Figure M–111. Dependence of Release Rate of Technetium-99 on Rate of Recharge for Diffusive Release Model

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