Title
CUMULATIVE RELEASES OF RADIONUCLIDES FROM UNCONTAINED WASTE PACKAGES

Author
Lee, W.W.L.

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Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

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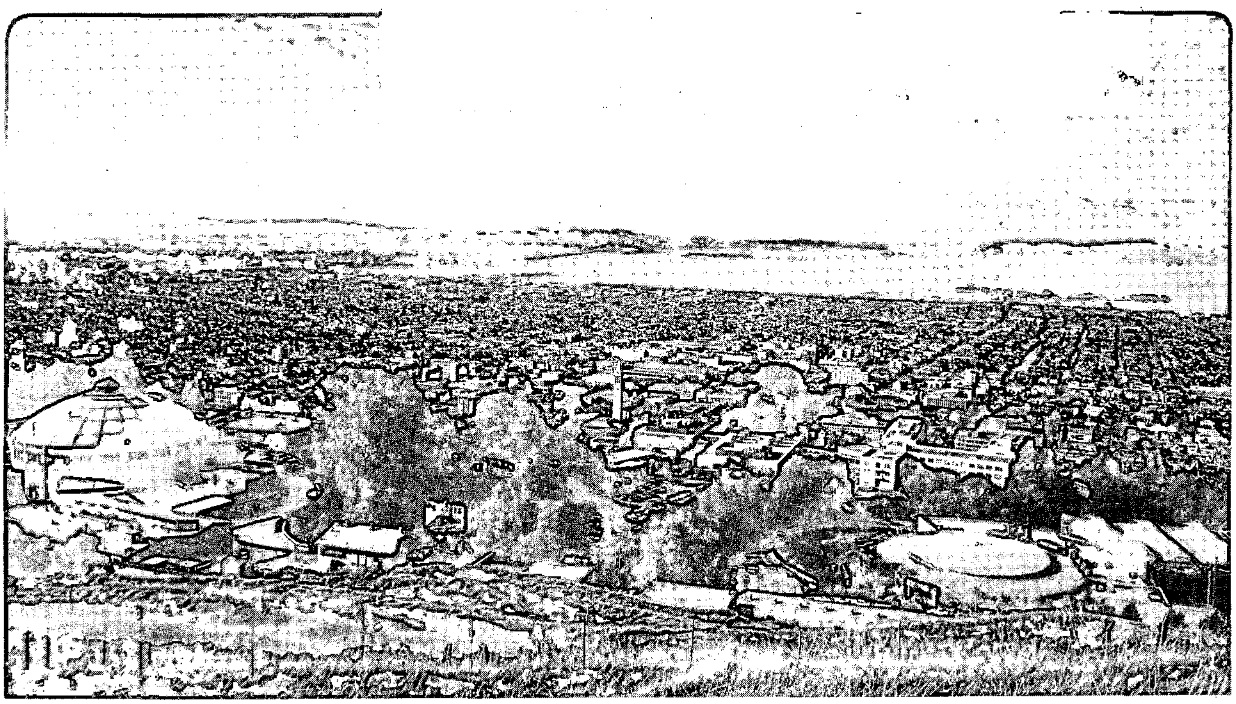

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CUMULATIVE RELEASES OF RADIONUCLIDES FROM UNCONTAINED WASTE PACKAGES

W. W.-L. Lee, C. L. Kim, P. L. Chambre', T. H. Pigford
Department of Nuclear Engineering
and
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

The U. S. Nuclear Regulatory Commission's performance objective for the waste package subsystem requires substantially complete containment of all radionuclides within the waste package for 300 to 1,000 years for anticipated processes and events[1]. This requirement has been interpreted by repository projects as requiring an envelope around the waste solid that will not be penetrated for 300 to 1,000 years. However, to provide a technical basis for further interpretation of the containment requirement, mass-transfer theory[2] can be used to predict the extent of radionuclide release from a waste solid into surrounding rock even in the absence of a separate containment envelope. It is possible that the barrier system of waste solid, backfill, and rock can result in substantial containment within the waste solid and backfill during time periods of interest. Calculations of 1000- and 10,000-year cumulative releases of radionuclides from a waste solid without separate containment are presented herein.

We assume a spherical-equivalent waste solid surrounded by backfill, assumed to be exposed directly to ground water shortly after its emplacement in saturated porous rock. Groundwater flow is low enough that dissolution is controlled by diffusion [2]. Table 1 lists parameters adopted for calculation, typical of a geologic repository with mildly reducing conditions. Calculated cumulative releases into the rock during 1,000 years and 10,000 years are given in Table 2. Also listed are the 10,000-year cumulative releases allowed by the EPA standard[3]. The cumulative releases into the rock fall well below the EPA allowed releases for the radionuclides considered in this calculation. Although the EPA cumulative-release standard applies to radionuclides reaching the accessible environment, it seems reasonable that if that standard can be met at the surface of the emplacement hole containment may be sufficiently or substantially complete within that hole. Thus, the eight most abundant radionuclides considered here can be substantially contained within the emplacement hole, even in the absence of a separate containment barrier.

The use of mass-transfer theory to predict the performance of waste repositories is considered a reliable and theoretically valid method[4]. Its use in addressing the NRC release-rate requirement[5] is being treated in other publications[6].

These calculations have neglected the effect of decay heat on solubilities and diffusion coefficients. A mass-transfer theory applicable to transient heating has been published[7] and some of its findings will be applied for similar calculations of cumulative release without separate containment.

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Table 1. Parameters Used in the Calculations

Part 1. General

Radius of Waste Form	82.6 cm
Waste Content	1.8 MTHM/package
Backfill Thickness	15.2 cm
Backfill Porosity	0.4
Rock Porosity	0.001
Diffusion Coefficient	10^{-6} cm^2/s

Part 2. Radionuclide Data

Nuclide	Half-Life (years)	Inventory at 360 yrs (Ci/MTIHM)	Elemental Solubility (Moles/L)	Distribution Coefficient (mL/g)
Am-241	432	2.0×10^{2}	1.0×10^{-10}	170
Am-242	152	1.1×10^{1}	1.0×10^{-10}	170
Am-243	7,380	1.4×10^{1}	1.0×10^{-10}	170
Cs-135	2.3×10^{6}	2.7×10^{-1}	1.2×10^{-1}	250
Pu-238	88	2.1×10^{3}	1.0×10^{-9}	21
Pu-239	2.4×10^{4}	2.9×10^{2}	1.0×10^{-9}	21
Tc-99	2.1×10^{5}	1.3×10^{1}	4.0×10^{-8}	0
U-234	2.4×10^{5}	1.2×10^{0}	4.2×10^{-9}	5

Table 2. Cumulative Releases at the Backfill/Rock Interface

Nuclide	Cumulative Release 1,000 years (Ci/1,000 MTIHM)	Cumulative Release 10,000 yeaars (Ci/1,000 MTIHM)	USEPA Limit at 10,000 years
Am-241	6.00×10^{-2}	7.34×10^{-1}	100
Am-242	3.84×10^{-3}	4.36×10^{-2}	100
Am-243	2.20×10^{-4}	4.09×10^{-3}	100
Cs-135	1.68×10^{-1}	2.46×10^{-1}	1000
Pu-238	1.08×10^{-1}	1.12	100
Pu-239	5.90×10^{-5}	2.29×10^{-4}	100
Tc-99	9.74×10^{-2}	3.43×10^{-1}	10,000
U-234	2.24×10^{-8}	7.56×10^{-8}	100

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LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720