NUREG-0782
Vol. 4

Draft Environmental Impact Statement on 10 CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Waste"

Appendices G-Q

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

September 1981

VOLUME IV

Table of Contents

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

List of Tables

List of Tables (Continued)

List of Tables (Continued)

List of Figures

- Placing higher activity material at greater depths (layering the higher activity waste).
- Filling the interstitial spaces between the disposed waste containers with cement grout.
- Use of barriers to intrusion (bio-barriers).

The first three items are straightforward. The burrowing depths of most animals, except some insects, typically are not more than one or two meters. Increasing the cover thickness (e.g., from one to two meters to three to four meters) would therefore place the waste below the burrowing depths of most burrowing animals. Layering the higher activity waste streams essentially eliminates the potential for intrusion into these waste streams. Contact, if it occurs, would be only with the lower activity waste streams. Grouting the disposed waste packages impedes intrusion into the disposal cells, reduces the potential for waste dispersion, and reduces the potential for increased ground-water migration.

Barriers against intrusion may also be used. One barrier which has been used with success against intrusion by burrowing animals is emplacement of a hard surface such as rip-rap, cobbles, or asphalt over the top of disposal trenches. The hard surface greatly discourages or eliminates burrowing mammals and has the added benefit of controlling potential wind and water erosion. Coatings of cobbles over filled disposal trenches are currently being routinely used at the Hanford Reservation, both at the disposal areas operated by DOE and the commercial disposal facility located within the reservation.

Over the past several years, work on development of biological barriers effective against deep rooted plants and burrowing insects in addition to burrowing mammals has been performed by Cline, et al., and this work is discussed in some detail in Appendix F. This work has included use of asphalt and cobble layers, as well as use of root toxins placed at sufficient depth below the surface to kill deep-rooted plants but allow shallow-rooted plants to grow. It is possible that herbicides could be used which would be nontoxic to the plant but would inhibit root growth.

To summarize Appendix F, the use of cobbles, asphalt, or other hardened layers would appear to be straightforward in application against intrusion by burrowing mammals. Additional work is required, however, to develop effective biological barriers against intrusion by plant roots, particularly in humid environments. In any case, construction of elaborate biological barriers could prove to be an expensive hinderance as long as trench subsidence was in evidence at a disposal facility. Subsidence would tend to crack rigid surfaces such as asphalt layers or concrete, thus reducing or eliminating their effectiveness. Repairs or restabilization activities would also tend to be more difficult and more expensive.

3. EROSION

Another source of potential environmental releases is through the effects of wind and water erosion. Through these mechanisms, the covers over disposal

trenches may be removed over time, eventually exposing the disposed wastes which then could be potentially dispersed into the environment through airborne or waterborne pathways. In addition, a significant erosion problem would reduce the ability to predict disposal facility impacts over time.

It is recognized that minimizing the effects of erosion is of significant importance when siting, designing and operating a disposal facility. The effects of erosion are site-specific and would be analyzed as part of individual licensing actions for a particular disposal facility. For some facilities--for example those located in an arid region having high winds--wind erosion may be of most significance. For facilities located in humid environments, gully or sheet erosion due to the action of water may be of most significance. Gully erosion would affect less of the disposed waste, but could occur over a shorter time frame. Sheet erosion would eventually effect a larger area, and hence a larger amount of the disposed waste, but would take longer to occur.

It is believed that the effects of erosion at a disposal facility can be minimized through proper siting, design, and operation to the point that it needn't be considered a problem. Practical measures which can be readily taken to minimize or eliminate this potential problem include the following examples:

- Avoid areas characterized by rapid erosion, such as floodplains, areas of high topographic relief, and so forth.

- Stabilize the site against erosion through application of a soil cover such as grass or a layer of rip-rap.

- If drainage channels are used at the facility, minimize gully erosion through appropriate engineering such as lining with rip-rap.

Still, it is difficult to predict the effectiveness of measures intended to minimize erosion over the long term, and it is instructive to obtain an upper-bound estimate of the level of potential exposures that could occur if through some reason the waste did become exposed through erosion. To do this, an estimate must be made of the length of time that it takes for the cover over the waste to be removed through weathering activities. As stated above, gully erosion could be a fairly rapid process. However, its effects would tend to be localized and if it were to occur, then it would probably occur during the 100-year institutional control period. During this time period, the disposal site would be under the surveillance and control of a governmental agency and steps could be taken to correct the problem. Sheet erosion, however, would appear to be a less perceptible, long-term potential problem.

3.1 <u>Water Erosion</u>

A short but illustrative discussion of soil-water erosion rates is provided by Healy and Rodgers in Reference 10. As observed by the authors, erosion rates can vary widely depending upon such site-specific factors as rainfall, soil type, ground slope, soil cover, and human activities. To calculate the potential erosion rate, use may be made of the universal soils loss equation (USLE). This equation has been used (or a derivative has been used) for a number of

years to estimate erosion rates from plowed agricultural fields. A derivative of the semi-emperical equation has also been used to determine erosion rates during highway and other forms of construction activities. As stated above, the equation is actually intended for use in determining erosion from plowed agricultural fields. The length of time over which the erosion rate is calculated is short and the conditions under which the equation is used (e.g., plowed fields) are those in which sheet erosion would be accentuated. Considerable care must be taken when applying the equation to a disposal facility. Still, the equation is useful as a basis of discussion of the variation in erosion rates and the types of factors which influence erosion rate.

A simplified derivative of the universal soil loss equation is as follows (Ref. 11):

A = R x K x LS x VM, where

A = The computed soil loss in tons/acre per year. This quantity may be converted to cubic meters using selected conversion factors.

B = The rainfall intensity factor, which is a measure of the erosion force of rainfall.

K = The soil erodibility factor, which is highly regional.

The next two parameters are of importance as they may be varied to control and minimize erosion:

LS = The topographic factor--e.g., the effect of length and steepness of slopes on the soil loss per unit area.

VM = The erosion control factor, which is a function of all erosion control measures such as vegetation, mechanical manipulation of the surface, chemical treatments, etc. For bare slopes, VM=1.

In general, a maximum rate of erosion is apparently reached in areas having precipitation on the order of 25 cm/yr (10 in/yr), with decreased rates in more humid as well as in more arid climates. The number and severity of rain storms is also an important factor. To determine the effect of rainfall, a rainfall erosion-index (or rainfall intensity factor) has been developed, which is a function of the total kinetic energy of a rainstorm as well as its maximum intensity over a 30-minute period. Iso-erodent maps are available giving regional values of this index and in the eastern states, this factor can vary from about 50 to about 600.

The soil erodibility factor accounts for the differences in erosion potential among different soils. This factor can vary widely--e.g., from 0.69 for a Dunkirk silt loam to 0.03 for an Albin gravelly loam (Ref. 10).

Of course, the gradient of the ground slope as well as the steepness of the ground slope are also important factors. Complicated formulas can be used to

determine the topographic factor for multiple slope lengths and gradients. One such formula is illustrated in Reference 11. In general, however, the factor is larger with larger gradients. Healy and Rodgers gives an example of this in Reference 10. "For a length of 60 m (200 ft.), the soil loss ratio varies from about 0.3 at a 2% gradient to about 6 at a slope of 20%."

The last factor--the erosion control (soil cover) factor--greatly influences the calculated erosion rate. For agricultural purposes, determining this factor can be complicated. It may, for example, be influenced by such factors as crop management techniques, growth stages of crops during periods of heavy rainfall, and so forth. However, as stated in Reference 10, "with established meadows of grass, alfalfa or clover, the soil loss rates are 0.4 to 2% of that from fallow land."

For purposes of waste management, this implies that a good soil cover over a disposal facility such as a thick vegetative carpet or a layer of rip-rap can reduce potential erosion rates from a given site (all other factors such as rainfall, soil erodibility, and topography being equal) by 2 or 3 orders of magnitude.

The combined effect of the different possible rainfall, soil erodibility, topography and soil cover factors can result in wide differences in erosion rates. For example, Table M.7, obtained from Reference 10, provides an illustration of different erosion and runoff rates for a number of widely scattered soil types, rainfall, crops, and so forth. The erosion rate of clean tillage can exceed that associated with dense soil covers by 2 to nearly 3 orders of magnitude.

Human activities such as construction of houses or roads can result in greater erosion rates with respect to agricultural activities while erosion rates associated with natural weathering activities are generally in a lower range. Table M.8, obtained from Reference 10, illustrates this. As can be seen, erosion rates from construction activities can be quite high. However, such erosion rates would only be temporary and after construction had ceased, erosion rates would quickly fall to much lower levels--perhaps to levels below those associated with preconstruction. Erosion rates for clean tilled farming activities can also be high (e.g., on the range of 10-60 tons per acre per year). However, it is again unlikely that such erosion rates would occur over long time periods. Continued erosion rates of that magnitude would result in a rapid loss in productivity of the farmland.

Natural erosion rates are an estimate based upon consideration of the volume of deposits in closed systems.

Given the above discussion it would appear that while the potential for water erosion is an important consideration for radioactive waste disposal, it is a site-specific phenomenon and can best be regulated as part of licensing actions for a specific disposal facility. However, it is useful on a generic basis to determine the range of potential exposures that could occur over the long term at the reference facility. To do this, an estimate must be made of the length of time that it would take for the disposal cell covers to be removed. One

Table M.7 Annual Soil and Water Losses per Acre from Five Widely Separated Types of Land Under Conditions of Clean Tillage and Dense Cover of Vegetation*

Soil, Location and Years of Measurements	Average Annual Precipitation	Slope	Clean-Tilled Crop		Dense Cover-Thick-Growing Crop		Approximate Number of Years to Remove 18 cm of Soil	
			Annual Soil Loss	Annual Water Runoff**	Annual Soil Loss	Annual Water Runoff**	Clean Tillage	Dense Cover
	(cm)	(%)	(tons)	(%)	(tons)	(%)		
Shelby silt loam, Bethany, MO, 1931-35.	88	8.0	68.78	28.31	0.29	9.30	16	3,900
Kirvin fine sandy loam, Tyler, TX, 1931-36.	104	8.75	27.95	20.92	0.124	1.15	49	11,100
Vernon fine sandy loam, Guthrie, OK, 1930-35.	84	7.7	24.29	14.22	0.032	1.23	50	38,200
Marshall silt loam, Clarinda, IA, 1933-35.	68	9.0	18.82	8.64	0.06	0.97	48	15,200
Cecil Clay loam, Statesville, NC, 1931-35.	115	10.0	22.58	10.21	0.012	0.33	51	95,800

*Measurements at the soil and water conservation experiment stations of the Soil Conservation Service.

**Of total precipitation.

Table M.8 Erosion Rates Under Varying Conditions

Soil or Rock Description	Use	Erosion Rate
		(tons/acre per year)
Igneous rock	Geologic past	0.08
Appalacian Mountains	Geologic past	0.7
Midcontinent farmland	Typical farming (other than clean tilled)	0.5-6
	Clean tilled	10-60
Urban or suburban	During construction	70-200

reference, (Ref. 12) in considering this question, postulated a range of one to six tons of soil lost per year. Reference 10 also assumed a range of one to six tons a year, and based on a bulk density for soil of 1.5 gm/cm^3, postulated a time period of from 2,000 to 13,000 years to remove 2 meters of soil cover over disposed waste.

Similarly, for purposes of this environmental impact statement, a time of 2,000 years is assumed to be required to uncover 2 meters of soil, or about 1,000 years per meter of cover over the disposed waste. This essentially assumes a soil loss of 6 tons per acre per year from the disposal trench. A continual (over 2,000 years) soil loss rate of this magnitude from the disposal facility is extremely unlikely. It ignores ground cover and other surface engineering measures that would be incorporated into the disposal facility design. The loss rate is at an upper range associated with typical farming activities. Such farming activities are unlikely to occur and if they do occur, it would be unlikely that a continual soil loss rate of 6 tons per year would be tolerated by a farmer. Such rates would probably reduce the productivity of the soils to unacceptable levels long before the 2 meters of soil thickness is lost.

In any case, after a time period equal to 1,000 years per meter of cover thickness, the trench covers are hypothetically assumed to be eroded away and the scenario is initiated. As a further conservatism, no credit for waste form is assumed for the erosion scenario. Neither is credit taken for barriers against erosion such as a rock cover or more elaborate measures such as disposing of the waste in walled trenches. The contaminated exposed soil/waste mixture is assumed to be carried by the water into the surface body water located one kilometer from the disposal facility. The natural mobilization rate calculated

for the reference facility (about 0.75 tons/acre/year) is used. The reduction in the activity due to deposition along the route is neglected and the soil/waste mixture is assumed to all dissolve in the surface water, where the water is used by an individual for consumption, crop irrigation, and so forth. The total exposures received by all significant pathways may be then calculated. Additional detail regarding the calculational procedure is provided in Appendix G.

Table M.9 presents the results of the calculations for each of the cases considered in the analysis carried out in Chapter 5 for ground-water migration. As discussed in Appendix G, the calculated exposures will vary depending upon such factors as the waste spectrum (e.g., the radionuclide concentrations), the disposal efficiency, the amount of land area exposed, the disposal cell cover thickness, and the density of the waste. Another factor is the placement of the waste to limit exposures to intruders--e.g., the amount of waste that must be layered to meet intruder exposure limitation requirements. In any case, all exposures seem to lie within a relatively small range. For example, exposures to all organs except thyroid range from about 0.05 mrem/yr to about 0.7 mrem/year. Exposures to the thyroid range from about 0.1 to 1 mrem/year. These calculated exposures are less (in some cases significantly less) than the 4 mrem/year limit for drinking water promulgated by the Environmental Protection Agency in 40 CFR 190. Given the conservatism of the calculational procedure, and the hypothetical nature of the institution's mechanisms (e.g., the facility would be sited and designed so that erosion would not be a problem), it is believed that actual waterborne erosional impacts would be much less.

It is also of interest to compare these calculated exposures to those corresponding to a "no action" case in regard to intruder exposures. In Chapter 4, "a base case" is considered in which no consideration is given to intruder exposures. Two waste streams included in this base case analysis--L-DECONRS and N-SOURCES--were excluded from cases 1 through 10 on Table M.9 due to the transuranic content of these streams. In addition, no consideration is given in the "no action case" to disposing of higher activity waste streams by methods, such as layering, that provide a barrier against intrusion. The corresponding waterborne erosion impacts are shown below in Table M.10 for waste spectrum 1. As can be seen, the calculated results for the base (no action) case are significantly higher (two orders of magnitude) for all organs except thyroid. In general, layering of the higher activity waste streams results in thyroid exposures of 10 less than the base case.

3.2 Wind Erosion

The mechanism for mobilization of particulates from soil by wind depends upon such factors as wind speed, soil properties, and the nature of the soil surface. Wind action results in three basic modes of particle motion: surface creep (particulates above approximately 500 μm in size), saltation (particles between approximately 100 μm and 500 μm in size), and airborne suspension (particles less than about 100 μm in size). Under surface creep, particles are rolled along the surface by the push of strong winds and by exchange of momentum after impact with smaller particles in saltation. Saltation consists of individual particles jumping and lurching within a few centimeters of the ground. Particles borne by airborne suspension may be carried through the atmosphere for long

Table M.9 Waterborne Radiological Impacts Assuming Erosion of the Facility Designs Considered in Chapter 5 Case Study

	Organ						
Case	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(millirems/yr to an individual)							
1	5.37E-2	4.64E-1	7.61E-2	1.19E-1	9.17E-2	4.26E-2	7.27E-2
2	5.37E-2	4.64E-1	7.61E-2	1.19E-1	9.17E-2	4.26E-2	7.27E-2
3	5.37E-2	4.64E-1	7.61E-2	1.19E-1	9.17E-2	4.26E-2	7.27E-2
1A	5.37E-2	4.64E-1	7.61E-2	1.19E-1	9.17E-2	4.26E-2	7.27E-2
4A	5.36E-2	4.63E-1	7.59E-2	1.19E-1	9.15E-2	4.25E-2	7.26E-2
4B	5.36E-2	4.63E-1	7.59E-2	1.19E-1	9.15E-2	4.25E-2	7.26E-2
4C	4.74E-2	4.15E-1	6.35E-2	1.14E-1	7.63E-2	3.78E-2	6.53E-2
4D	4.74E-2	4.15E-1	6.34E-2	1.14E-1	7.62E-2	3.78E-2	6.53E-2
4E	4.74E-2	4.15E-1	6.34E-2	1.14E-1	7.62E-2	3.78E-2	6.53E-2
5	5.23E-2	4.56E-1	9.06E-2	8.79E-1	6.11E-2	2.37E-2	1.17E-1
6	4.74E-2	4.15E-1	6.35E-2	1.14E-1	7.63E-2	3.78E-2	6.53E-2
7A	6.42E-2	4.93E-1	7.81E-2	9.73E-2	9.73E-2	5.33E-2	8.13E-2
7B	9.76E-2	7.76E-1	1.61E-1	1.00E+0	1.32E-1	6.04E-2	1.95E-1
7C	9.76E-2	7.76E-1	1.61E-1	1.00E+0	1.32E-1	6.04E-2	1.95E-1
7D	8.87E-2	7.03E-1	1.41E-1	9.94E-1	1.08E-1	5.41E-2	1.81E-1
8	7.49E-2	6.35E-1	1.28E-1	9.82E-1	9.37E-2	4.02E-2	1.68E-1
9	4.69E-2	4.29E-1	8.52E-2	8.74E-1	5.57E-2	1.82E-2	1.11E-1
10A	4.74E-2	4.15E-1	6.35E-2	1.14E-1	7.63E-2	3.78E-2	6.53E-2
10B	8.87E-2	7.03E-1	1.41E-1	9.94E-1	1.08E-1	5.41E-2	1.81E-1
10C	8.85E-2	7.01E-1	1.41E-1	9.92E-1	1.07E-1	5.40E-2	1.81E-1
12A	9.76E-2	7.76E-1	1.61E-1	1.00E+0	1.32E-1	6.04E-2	1.95E-1
12B	8.87E-2	7.03E-1	1.41E-1	9.94E-1	1.08E-1	5.41E-2	1.81E-1
12C	9.74E-2	7.75E-1	1.61E-1	9.98E-1	1.31E-1	6.03E-2	1.94E-1
12D	8.85E-2	7.01E-1	1.41E-1	9.92E-1	1.07E-1	5.40E-2	1.81E-1
12E	9.74E-2	7.75E-1	1.61E-1	9.98E-1	1.31E-1	6.03E-2	1.94E-1
12F	8.85E-2	7.01E-1	1.41E-1	9.92E-1	1.07E-1	5.40E-2	1.81E-1

Table M.10 Waterborne Erosion Impacts for the Base Case

Organ Exposures (millirem/yr)

Body	Bone	Liver	Thyroid	Kidney	Lung	GI
3.203	171.2	17.36	1.036	14.50	0.424	10.17

periods and to great distances from their original location. The mechanism by which fine particles are lifted off the ground is different from that of saltation. Samples of soil composed only of fine dust particles may be extremely resistant to wind erosion, but in mixtures with coarser grains these particles move readily. Thus, suspension of fine dust in air may be primarily the results of movement of grains in saltation (Ref. 7).

Calculational procedures are available to estimate the soil loss (in gm/m^2-sec) from an exposed area. Such calculations depend upon such factors as soil erodibility, soil-ridge roughness, climate, and the presence of a cover which would preclude or greatly reduce wind erosion. As in the case of water erosion, such covers could include application of a vegetative cover or a layer of gravel, rocks, or rip-rap. At the reference disposal facility, the soil loss for bare soil is calculated to be 4.1 E-7 g/m^2-sec. Assuming a soil density of 1.6 gm/cm^3 and a trench cover thickness of 2 meters, this implies that the wind erosion rate of a bare cover would be about 0.001 cm/yr. This would imply that it would take 250,000 years for the waste to become exposed. A longer period of time would be necessary to expose the waste if stabilizing soil covers such as a layer of rocks are applied.

However, for the purposes of bounding potential exposures due to water erosion, it was previously assumed that wastes would be exposed at a time period equal to 1,000 years per meter of cover. Given this assumption, a bounding estimate of the impacts of wind erosion at the reference disposal facility can be estimated. Similarly to the water erosion case, the equations for calculating total volume of soil/waste mixture assumed to be mobilized after a long time period (2,000 years for the reference case) are described in Appendix G.

Conservatively assuming no credit for waste form, the total population exposures within 50 miles of the facility are calculated for each of the case study cases in Chapter 5 and presented in Table M.11. The population is again assumed to be three times the size of the population within the vicinity of the facility while the facility is operating. As can be seen, such exposures are very small and are an order of magnitude or so below those exposures calculated during the hypothetical operation of a regional incinerator (1870 man-millirem/yr).

The exposures calculated and presented in Table M.11 can again be compared with those corresponding to the base (no action) case considered in Chapter 4. For random disposal, a thin cover, and waste spectrum 1, these exposures are calculated to be as shown in the following Table M.12.

Table M.11 Airborne Radiological Impacts Assuming Erosion of the Facility Designs Considered in Chapter 5 Case Study

	Organ						
Case	Body	Bone	Liver	Thyroid	Kidney	Lung	GI
(man-millirem/yr)							
1	4.19	80.13	55.32	5.38	21.21	76.43	0.21
2	4.19	80.13	55.32	5.38	21.21	76.43	0.21
3	4.19	80.13	55.32	5.38	21.21	76.43	0.21
1A	4.19	80.13	55.32	5.38	21.21	76.43	0.21
4A	4.19	80.01	55.24	5.37	21.18	76.31	0.21
4B	4.19	80.01	55.24	5.37	21.18	76.31	0.21
4C	3.48	69.52	46.05	5.36	16.14	74.39	0.19
4D	3.48	69.46	46.01	5.35	16.13	74.33	0.19
4E	3.48	69.46	46.01	5.35	16.13	74.33	0.19
5	4.23	84.87	55.02	58.67	18.02	84.85	0.24
6	3.48	69.46	46.01	5.36	16.14	74.39	0.19
7A	3.11	59.29	40.19	3.17	15.21	70.66	0.23
7B	7.31	137.6	95.00	64.53	36.03	111.9	0.38
7C	7.31	137.6	95.00	64.53	36.03	111.9	0.38
7D	6.11	119.8	79.40	64.51	27.50	108.6	0.35
8	6.09	119.8	79.50	64.58	27.51	108.8	0.32
9	4.22	84.81	55.01	58.66	18.01	84.84	0.22
10A	3.48	69.52	46.05	5.36	16.14	74.39	0.19
10B	6.11	119.8	79.40	64.51	27.50	108.6	0.35
10C	6.10	119.5	79.22	64.36	27.43	108.4	0.35

Table M.12 Airborne Erosion Impacts for the Base Case

Organ Exposures (man-millirems/yr)

Body	Bone	Liver	Thyroid	Kidney	Lung	GI
2.61E+3	5.48E+4	3.60E+4	65.80	1.18E+4	4.15E+4	54.28

The base case (no action) exposures are again seen to be one or more orders of magnitude higher.

REFERENCES

1. U.S. Environmental Protection Agency, Draft Environmental Impact Statement on the Proposed Guidelines for the Landfill Disposal of Solid Waste, Office of Solid Waste, March 1979.

2. Husain, L., J. M. Matuszek, J. Hutchinson, and M. Wahlen, Chemical and Radiochemical Character of a Low-Level Radioactive Waste Burial Site, Management of Low-Level Radioactive Waste, Vol. 2, Pergamon Press, 1979.

3. Lu, A. H,. and J. M. Matuszek, 1978, Transport through a Trench Cover of Gaseous Tritiated Compounds from Buried Radioactive Wastes, presented at the International Symposium on the Behavior of Tritium in the Environment, San Francisco, California, October 16-20, 1978.

4. Matuszek J. M., M. E. Wahlen, C. O. Kunz, and J. H. Hutchinson, 1978. Is the Removal of ^{14}C from Nuclear Reactor Effluents a Plausible Regulatory Practice?, presented at Conference on Effluent and Environmental Radiation Surveillance, Atlanta, Georgia, July 9-14, 1978.

5. Clancy, J., O. Oztunali, H. Tuchfeld, and T. Van Arsdale, Maxey Flats Facility Studies Progress Report No. 2, January-March 1979., Dames & Moore, May 1979.

6. Clancy, J., Trench Gas Study at the Beatty, Low-Level Radioactive Waste Disposal Site, Dames & Moore, October 1978.

7. U.S. Nuclear Regulatory Commission, Final Generic Environmental Impact Statement on Uranium Milling, Office of Nuclear Material Safety and Safeguards, NUREG-0706, September 1980.

8. U. S. Nuclear Regulatory Commission, 10 CFR 20: Biomedical Waste Disposal, Federal Register, 46 FR 16230, March 11, 1981.

9. Stone, R., Controlling the Underground Movement of Methane from Sanitary Land Fills, Civil-Engineering-ASCE.

10. Healy, J. W., and J. C. Rodgers, Limits for the Department of Energy Transuranic Wastes, Los Alamos Scientific Laboratory, LA-UR-79-100,

11. Oztunali, O. I., G. Re', Cr J. Pitt., Data Base for Radioactive Waste Management: Volume 4, Impacts Analysis Methodology Report, NUREG/CR-1759, Dames & Moore for NRC, to be published in 1981.

12. Adam, J. A., and V. L. Rogers, A Classification System for Radioactive Waste Disposal--What Waste Goes Where?, NUREG-0456, Ford, Bacon, & Davis, Utah for NRC, June 1978.