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on 10 CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Waste"

Main Report

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VOLUME II

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4.4 CONCLUSIONS AND COMPARATIVE EVALUATION OF ALTERNATIVES

In summary, there are many potential methods which could be implemented to reduce potential exposures to an inadvertent intruder. All methods would involve increased costs for disposal--some significantly. In addition, many waste streams contain very small quantities of radioactivity and it would not appear to be reasonable to require the additional expense for all waste streams, particularly considering the hypothetical nature of the intrusion scenarios. Some criteria--preferentially based upon a dose level to a few individuals--is needed to distinguish between waste streams which should be disposed with additional protection against potential intrusion and those waste streams for which this would not be necessary. Such a dose level would also establish the level of safety to assure protection of an inadvertent intruder--i.e., a performance objective for intrusion.

It also appears that for most cases, simply layering the disposed wastes would provide sufficient protection to an intruder. For some streams perhaps even more additional protection would be needed--for example, use of a walled trench. Finally, some waste streams may not be suitable for near-surface disposal.

In determining which waste streams may not be acceptable for near-surface disposal, one of the key questions is how long barriers to a potential intruder may be expected to last. Such barriers, of course, would be expected to last several hundred years but not forever. Some barriers may last longer than others. For example, the effectiveness of a "hot waste facility" (walled trench) discussed above to deter the actions of a potential intruder could be expected to last longer than the intruder barrier provided by layering. As discussed above, the "hot waste facility" is assumed to consist in this EIS of a disposal trench which has a 0.3 m thick concrete base, 0.3 m thick concrete walls, and a one-meter thick concrete cap. This trench may be then covered over with fill.

From the analyses performed for this EIS, it can be seen that due to radioactive decay, exposures to a potential inadvertent intruder from almost all waste streams typically considered to be LLW fall to a few millirems after a few hundred years--e.g., 500 years. After 500 years, only a few waste streams are estimated to result in potential intruder exposures of a few hundred millirems. Very few (e.g., one or two) streams having small volumes are estimated to result in potential intruder exposures exceeding 500 mrem after 500 years. A time period of 1,000 years was assumed for a "hot waste facility" to provide an upper estimate of the degree to which near-surface disposal techniques can reduce potential intruder exposures.

On the other hand, waste streams that are generally considered to be "high-level waste" (e.g., spent reactor fuel, solidified first solvent extraction stages from a nuclear fuel reprocessing plant) contain much higher initial levels of radioactivity. Typically, the potential hazard from high-level waste disposal is dominated by fission products over approximately the first 600 years. After that approximate time period, most of the fission-product activity has decayed, except for iodine-129 and technetium-99; radioactivity is dominated thereafter by the actinides--e.g., U, Np, Pu, Am, Cm and their daughters.

This point was recognized by NRC during development of the regulation 10 CFR 60 for geologic disposal of high-level waste. In the Federal Register Advance Notice of Proposed Rulemaking on this rule (Ref. 10), there was included a draft requirement that high-level wastes should be placed into a canister that would last for 1,000 years to allow decay of the fission products. This requirement was later included as part of the Part 60 rule proposed in July 1981 (Ref. 11). It is apparent, then, that wastes which still contain appreciable activity after several hundred years (e.g., 500 years) would appear to more closely resemble high-level waste than what is usually considered to be low-level waste.

Finally, limitations on the effectiveness of barriers to a potential inadvertent intruder was discussed at the regional workshops on the Part 61 regulation. At these workshops, there appeared to be general agreement that a time period of 500 years seemed appropriate for most easy-to-implement intruder barriers.

Based upon the analyses and discussion of the previous subsections, the following conclusions can be reached:

1. The potential for inadvertent human intrusion into a closed disposal facility at some point after closure of the disposal facility is likely. Extensive intrusion activities such as major housing or apartment construction are unlikely. The potential exposures from inadvertent intrusion are relatively high for the first few hundred years (i.e., 3-6 rem/year) but, provided a few waste streams are removed, then drop to a low level (few mrem/year).

2. Some waste streams present relatively little hazard to an inadvertent intruder. Some present an initial high potential hazard. If inadvertent intruders can be protected against contacting these latter waste streams for a few hundred years, then such waste streams present much reduced potential hazards. Some waste streams may not be acceptable for near-surface disposal.

3. The extent and consequences of potential inadvertent intrusion are related to waste form, design, and operating practices. For example, improved waste form and packaging can reduce potential exposures through inhalation and food consumption pathways. Volume reduction may increase exposures from direct gamma radiation. If the waste is in a structually stable form and segregated from other wastes, then as long as the structural stability is retained, the possibility of extensive inadvertent intrusion activities is not considered credible.

4. Natural and engineered barriers can be used to reduce potential intruder exposures. However, there is a limit (e.g., 500 years) as to how long such barriers can be expected to last.

5. Institutional controls can be effective in reducing the potential for inadvertent intrusion and in reducing potential intruder exposures.

Two aspects must be analyzed in further detail and specific limits developed to determine the disposal requirements of different LLW streams based on protection

the end of institutional controls. Areas that are remote and less densely populated would generally be less likely to be immediately utilized, reducing the potential for inadvertent intrusion. In addition, the site should not have any extensive natural resources on the ground surface, in the hydrogeologic units used for disposal or at greater depth such as to encourage drilling or excavation within the site after institutional controls end. Sites having resources at much greater depths below the disposed waste would be acceptable provided the exploitation of such resources would not affect the performance of the facility (e.g., lead to increased ground-water contact with disposal waste or result in decreased ground water travel times).

4.6.3 Design and Operations

Requirement

1. Higher concentration waste presenting higher hazard potential to an inadvertent intruder must be disposed of at a minimum depth (to the top of the waste) of 5 meters below final grade (or the surface of the cover) or must be disposed of with natural or engineered barriers that are designed to protect against inadvertent intrusion for at least 500 years.

2. Compressible wastes shall be segregated from and disposed of separately from waste in a stable noncompressible form.

Analysis

Many alternatives may be applied to reduce the impacts of inadvertent intrusion. Many have either been applied in the past at existing disposal facilities or will require only minor modification to existing designs and operational practices. Those that NRC examined in the earlier analysis were:

- Use of thicker disposal cell covers
- Use of special waste disposal cells such as caissons, walled trenches, or other "engineered structures"
- Layered disposal
- Slit trench disposal
- Grouting
- Engineered intruder barrier

The results of the earlier analysis indicate that depth of burial (i.e., layering the waste) is the easiest to implement technically and costs the least. In this case, the more active waste would be preferentially placed toward the bottom of the trench. The potential intruder would tend to contact the lower-activity waste. Since many of high-activity waste streams which could be disposed in this manner would also be expected to contain high-surface gamma radiation levels, this technique would also help to reduce potential occupational exposures to disposal facility workers. The hot waste facility analyzed--a type of engineered structure--is probably the most difficult to implement technically and costs the most. Others fall in between except for significantly different methods of disposal (e.g., mined cavity disposal). To

maintain flexibility in assuring protection of the inadvertent intruder by placing greater controls on the higher activity wastes, NRC selected no specific prescriptive requirement. Such flexibility will allow for regional differences in site characteristics, different facility designs, and individual preferences of disposal facility operators.

In determining which waste streams may not be acceptable for near-surface disposal, one of the questions is how long barriers to a potential intruder may be expected to last. Such barriers, of course, would be expected to last several hundred years but not forever. Some barriers may last longer than others. For example, the effectiveness of the "hot waste facility" discussed above to deter the actions of a potential intruder would be expected to last longer than a disposal method such as layering. From the analyses performed earlier in the EIS, it can be seen that due to radioactive decay, exposures to a potential intruder from almost all waste streams typically considered to be LLW have fallen to a few millirems after a few hundred years--e.g., 500 years. After 500 years, only a few waste streams are estimated to result in potential intruder exposures of a few hundred millirems. Very few (e.g., one or two streams) having small volumes are estimated to result in potential intruder exposures exceeding 500 mrem after 500 years.

The segregation of compressible wastes is discussed in the concluding section on waste form.

4.6.4 Waste Form and Packaging

Requirement

Higher activity waste shall have structural stability. Structural stability can be provided by the waste form itself, processing the waste to a stable form, or placing the waste in a disposal container or structure that provides stability after disposal. Void spaces within the waste and between the waste and its package shall be reduced to the extent practicable. The waste must maintain its physical dimensions and consistency under conditions of the compressive load, radiation, and biodegradation to be encountered in disposal.

Analysis

In general, placing the higher activity waste into a stable form and disposing of them together in a separate disposal unit segregated from compressible wastes reduces the impacts to a potential inadvertent intruder. The waste is less available for inhalation and uptake, and someone intruding into the site would be more likely to identify that they were not digging in soil if they found the remains of solid waste, and would take action to find out what it was before proceeding too far. Other details regarding analysis of this requirement, alternatives considered, and the preferred alternative selected by NRC are set out in Chapter 5.

of Appendix F. The uptake and dispersion of radioactivity by plants and animals has not been reported at commercial disposal facilities. The impacts from these documented cases have not been of major public health and safety concern. Actual uptake and dispersion impacts of plant and animal intrusion into disposed wastes would be site specific and difficult to predict due to differences in climate, plant and animal species and waste characteristics. The last effect of plant and animal intrusion--that of increasing percolation into disposal cells--was considered during the ground-water analysis in Section 5.2

In Appendix F, NRC looked at a number of ways in which the occurrence of plant and animal intrusion could be minimized or eliminated, including:

1. Increasing the thickness of earth fill between the top of the disposed waste and the disposal cell surfaces;

2. Placing higher activity material at greater depths;

3. Improvements in waste form; and

4. Using biological barriers such as rip-rap, cobbles, asphalt, root toxins and herbicides.

These are discussed in greater detail in Section 2.2.4 of Appendix F and in Section 2.0 of Appendix M. NRC concluded that the methods that would be applied to reduce impacts to man due to human intrusion and migration would also generally serve to reduce the potential impacts of plant and animal intrusion (e.g., thicker trench caps and placing high or activity waste deeper). With respect to specific engineered biological barriers, NRC concluded that such barriers may be useful as a means of helping to reduce potential ground-water migration to levels as low as reasonably achievable. However, additional work is believed to be needed regarding the application and use of biological barriers before specific requirements for their use could be established. For example, it is believed that the effectiveness of such biological barriers would be seriously reduced as long as instability of the disposal cells was a problem. The presence of the barriers may also make maintenance of unstable disposal cells more difficult and more expensive. NRC therefore concluded that at this time it is of more fundamental importance to concentrate on methods to achieve greater disposal cell stability. Thus, in designing disposal cell covers, plant and animal intrusion should be considered on a site-specific basis but requiring specific actions to include barriers to such intrusion is not believed to be generally appropriate at this time.

5.4.3 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 could then be potentially dispersed into the environment through airborne or water-borne pathways. In addition, a significant erosion problem would reduce the predictability of the disposal facility performance over time.

It is recognized that minimizing the effects of erosion is of significant importance when siting, designing and operating a disposal facility. Avoidance of areas which could result in erosion problems has been already addressed in the basic siting considerations set out in Appendix E. The effects of erosion and the types 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 effect 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 need not 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 flood plains, 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 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 most likely be identified 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, longer-term potential problem.

A discussion of factors which influence wind and water erosion, as well as typical erosion rates in various parts of the country, is provided in Appendix M. For the 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 continuous (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. 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. The contaminated exposed soil/waste mixture is assumed to be carried by the water into a 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 then be calculated.

Similarly, the effects of wind dispersal of the soil/waste mass exposed by the sheet erosion to the surrounding population are calculated. Details of the calculational procedures used to estimate surface water erosion impacts to individuals and airborne impacts to populations are provided in Appendix G. In these calculations, no credit is assumed for waste form.

The results of these calculations for the 20 cases considered in Section 5.2 in the ground-water migration case study are set out in Tables 5.26 and 5.27. As can be seen, the hypothetical waterborne exposures range from about .1 to 1 mrem to thyroid. All organ exposures are less than 4 mrem/year. Similarly, the hypothetical airborne exposures within 50 miles of the disposal facility range from about 3.5 to 7.3 man-mrem to whole body and from about 70 to 138 man-mrem to bone. The population is 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 waste incinerator (See Chapter 6).

5.4.4 Summary

The previous three sections investigated three additional pathways for potential long-term exposure of the public: gaseous releases from decomposing wastes, plant and animal intrusion, and erosion of the disposal facility. None of these three pathways would appear to result in potential exposures which would exceed the ground-water performance objective developed in Section 5.3.

For each of these potential pathways, there are a number of actions which may be taken to minimize such releases. By and large, such actions also serve to reduce potential exposures to humans through ground-water and intrusion pathways, as well as reduce the need for long-term maintenance of the site. For example, gaseous releases can be reduced by assuring stable site conditions. Erosion is a slow, long-term process which can be controlled through proper siting and good operational techniques. Impacts from plant and animal intrusion can be reduced through engineering designs applied to reduce ground-water migration and potential intruder exposures.

radionuclides, a better approach would be to establish inventory limits on a site and facility specific basis for those nuclides that are important with respect to ground-water migration.

In the previous analysis in Chapter 5, the NRC staff has identified three isotopes which are both long lived and mobile. That is, the isotopes move with the approximate speed of the ground water and ion exchange has relatively little effect to retard movement. These isotopes include C-14 (5,730 year half-life), Tc-99 (2.12×10^5 year half-life), and I-129 (1.7×10^7 year half-life). These isotopes have been identified as those contributing the principal long-term ground-water impacts. Tritium has also been identified as an isotope resulting in potentially significant ground-water impacts. Although it is relatively short lived (12.3 year half-life), it has the highest leach factor of the radionuclides considered in the analysis and has a retardation factor equal to 1 (moves with the speed of ground water). In addition, tritium composes the largest inventory of all the radionuclides disposed in the reference disposal facility. As shown in Chapter 5, impacts due to migration of tritium are almost totally observed close to the disposal facility, and it is the most significant contributor to exposures at the boundary well. Farther away from the disposal facility--e.g., at the population well and surface water access location--the ground-water migration time is such that tritium decays to the point that it is not a particular problem.

For these four isotopes, NRC staff believes that each disposal facility should be analyzed on a case-by-case basis and based on the analysis, inventory limits established for each facility that should not be exceeded.

In addition, the analyses in Chapter 5 also identified the fact that the presence of certain chemicals (e.g. chelating agents) in large concentrations in waste increased the potential for migration of radionuclides. Small quantities of these agents contained in waste do not significantly increase the potential for migration. Large single or multiple shipments, however, could affect the long-term ground-water impacts. To address these aspects, wastes containing chelating agents in relatively large amounts (defined by NRC to exceed 0.1% by weight) should be disposed of only upon prior approval of the Commission. This will enable site specific consideration of the increased potential for migration that disposal of these chemicals at the site might present.

7.4 FINAL CLASSIFICATION

This section presents the final classification of waste for near-surface disposal based upon consideration of the previous three sections of this chapter. This classification is presented as a list of radionuclides in Table 7.2. In the table, Column 1 lists the maximum concentrations ($\mu Ci/cm^3$) for "Class A segregated waste." Above these concentrations, the waste must be placed into a stable waste form and disposed in a segregated manner from unstable waste, and so becomes "Class B stable waste." Column 2 presents a list of concentrations above which the Class B stable waste becomes "Class C intruder waste." That is, these wastes must be in a stable waste form, segregated from unstable waste forms, and also disposed with a barrier to an intruder. This barrier

Table 7.2 Waste Classification Table

Isotope	Column 1 Maximum Concentration for Class A Segregated Waste. Above This, It Is Class B Stable Waste μCi/cm³	Column 2 Concentrations Above Which Some Wastes Become Class C Intruder Waste μCi/cm³	Column 3 Maximum Concentration For Any Waste Class μCi/cm³
Any with half-life less than 5 years	700	70,000	Theoretical maximum specific activity
H-3	40	10^8	Theoretical maximum* Specific Activity
C-14	0.8	0.8	0.8*
Ni-59	2.2	2.2	2.2
Co-60	700	70,000	Theoretical maximum specific activity
Ni-63	3.5	70	70
Nb-94	0.002	0.002	0.002
Sr-90	0.04	150	700
Tc-99	0.3	0.3	0.3*
I-129	0.008	0.008	0.008*
Cs-135	84	84	84
Cs-137	1.0	44	4600
Enriched Uranium	0.04	0.04	0.04
Natural or Depleted uranium	0.05	0.05	0.05
Alpha-emitting transuranic isotopes			10 nCi/g
Pu-241			350 nCi/g

*Near-surface disposal facilities will be limited to a specified quantity for the disposal site. This quantity will be determined at the time the license is issued and will be governed largely by the characteristics of the site.

For isotopes contained in metals, metal alloys, or permanently fixed on metal as contamination, the values above may be increased by a factor of ten, except natural or depleted uranium which can be the natural specific activity.

For isotopes not listed above, use the values for Sr-90 for beta-emitting isotopes with little or no gamma radiation; the values for Cs-137 for beta-emitting isotopes with significant gamma radiation; and the values for U-235 for alpha-emitting isotopes other than radium.

Wastes containing chelating agents in concentrations greater than 0.1% are not permitted except as specifically approved by the Commission.

For mixtures of the above isotopes, the sum of ratios of an isotope concentration in waste to the concentration in the above table shall not exceed one for any waste class.

Concentrations may be averaged over the volume of the package. For a 55-gallon drum, multiply the concentration limits by 200,000 to determine allowable total activity.

Until establishment and adoption of other values or criteria, the values in this table (or greater concentrations as may be approved by the Commission in particular cases) shall be used in categorizing waste for near-surface disposal.

could take many forms (e.g., concrete covers), but the minimum acceptable barrier would be disposal so that a minimum of 5 meters of earth or lower activity (Class B) waste, or a combination thereof, separates the waste from the potential inadvertent intruder. Other types of barriers would also be considered on a case-by-case basis.

Column 3 presents a list of radionuclide concentrations above which the waste would generally not be considered suitable for near-surface disposal. Wastes which exceed this concentration would need to be disposed of by disposal methods providing greater protection against potential intrusion. These methods could include much deeper disposal, mined cavity disposal, or special engineered disposal techniques. As noted in Chapter 2, NRC plans to address these other methods in subsequent rulemaking actions.

As discussed in Section 7.1, NRC also considered the use of a specially designed and engineered near-surface disposal facility (a "hot waste" facility) for disposal of wastes containing radionuclides in concentrations exceeding those listed in Column 3. NRC has not listed these concentrations because at this time staff believes that there are some uncertainties involved in use of such a facility and the volume of waste which could require disposal by this method would be small. NRC staff would prefer to address use of this potential disposal method on a case-by-case basis. From the analysis performed, however, the NRC staff believes that such an engineered disposal method would be suitable for wastes containing higher (than Column 3) concentrations of relatively short-lived isotopes such as Cs-137, Sr-90, or Ni-63. The additional long-term protection from longer-lived isotopes would be negligible.

Waste form requirements for the three classes of waste are presented in Table 7.3. These requirements were developed based upon the analyses in Chapters 4 through 6, and can be separated into <u>minimum</u> requirements and <u>stability</u> requirements. The minimum requirements are principally meant to help assure operational safety during handling and disposal, and should be met by all waste classes. The stability requirements are to be met by Classes B and C and are mainly intended to help provide long term structural stability and to minimize potential for inadvertent intrusion into and migration from Class B and Class C waste. In addition, each package of waste must be labeled to identify whether it is Class A, B or C waste and the total activity of H-3, C-14, I-129 and Tc-99 must be shown in the shipping manifest to enable the site operator to maintain an inventory of these isotopes disposed of at each site.

Alpha-emitting transuranic isotopes with a half life greater than 5 years are limited to 10 nCi/gm for near surface disposal. For Pu-241, which is a beta emitter and decays to Am-241, a limit of 350 nCi/gm is established.

As shown on the table, there is no upper limit on the allowable concentration of any isotope with a half-life under 5 years, H-3, or Co-60. The calculated limits exceed the natural specific activity of the isotopes. For isotopes with half-lives less than 5 years in Columns 1 and 2, NRC staff have used the concentration limits for Co-60. This is believed to be conservative, since Co-60 emits two energetic gamma rays. As discussed earlier, there is little cause for concern for potential intruder impacts for isotopes with half-lives less