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BRANCH TECHNICAL POSITION ON CONCENTRATION AVERAGING AND ENCAPSULATION

Contents

Definitions and Glossary of Terms for this Branch Technical Position

Classification-controlling radionuclides	A nuclide in the waste in concentrations greater than: 1% of the concentration of that nuclide listed in Table 1 of 10 CFR 61 or 1% of the applicable class-dependent concentration of that nuclide in Table 2 of 10 CFR 61, Column 2 or 3.
Heterogeneous waste mixture	Waste composed of multiple items that do not have reasonably similar *radionuclide concentrations.*
Heterogeneous mixture of similar waste types	Waste composed of multiple items that have *similar physical properties*, and reasonably *dissimilar radionuclide concentrations.*
Homogeneous waste	Waste in which the *radionuclide concentrations* are likely to approach uniformity in the context of the intruder scenarios used to establish the values included in Tables 1 and 2 of 10 CFR 61.55.
Homogenous waste type	A waste type that meets the definition of a homogeneous waste. As discussed more fully in the text, such a waste type would include, for example, spent ion exchange resins or contaminated soil.
Nuclides other than primary gamma-emitting nuclides	Tritium (H-3), Carbon-14 (C-14), Nickel-59 (Ni-59), Nickel-63 (Ni-63), and alpha-emitting transuranics with half-life > 5 years (except Pu-241 and Cm-242).
Primary gamma-emitting nuclides	Cobalt-60 (Co-60), Niobium-94 (Nb-94), and Cesium-137/Barium-137m (Cs-137/Ba-137m))
Waste type	A waste stream with *similar physical properties.* A drum containing pieces of activated stainless steel is an example of a container of wastes of a similar waste type.

1. Introduction, Purpose and Scope

Each shipment of radioactive waste to a licensed low-level radioactive waste land disposal facility must be accompanied by a shipment manifest. Appendix G to the U.S. Nuclear Regulatory Commission's (NRC's) 10 Code of Federal Regulations (CFR) Part 20 requires licensees to certify that each waste package listed on the manifest is properly classified as Class A, B, or C in accordance with 10 CFR 61.55.

For classifying wastes as Class A, B, or C, §61.55(a)(8) states that "…The concentration of a radionuclide may be averaged over the volume of the waste, or weight of the waste if the units are expressed as nanocuries per gram." This §61.55(a)(8) requirement applies to packages of reasonably homogenous waste. However, not all waste packages contain reasonably homogenous waste, and this Branch Technical Position (BTP) provides guidance on the interpretation of §61.55(a)(8) as it applies to the classification of specific wastes and mixtures of wastes for disposal under 10 CFR Part 61.

This BTP also establishes the NRC policy on encapsulation of low-level radioactive waste (LLRW) for disposal under Part 61. This BTP applies to the classification of waste packages; guidance for averaging across multiple waste packages is outside the scope of this BTP. This guidance does not in any way alter a licensee's obligation to meet the waste classification concentration limits in §61.55.

It should be noted that the requirements set by disposal facilities licensed by Agreement States (e.g., requirements for encapsulated waste) may differ from this guidance. Waste generators should consult with disposal site operators or appropriate regulatory authorities before classifying LLRW.

2. Relationship between 1983 BTP, 1995 BTP and this BTP

A Technical Position on radioactive waste classification and waste form was developed in 1983 (U.S. NRC, 1983). This initial Technical Position included section C.3, "Concentration Volumes and Masses," that provided guidance to waste generators on the interpretation of §61.55(a)(8).

Section C.3 of the 1983 Technical Position was replaced by the *Branch Technical Position on Concentration Averaging and Encapsulation* dated January 17, 1995 (U.S. NRC, 1995). The other sections of the 1983 Technical Position remain in effect, with the exception of the corrections noted in the footnote below.[1]

To ensure that gamma-emitting hot spots do not compromise the protection of the inadvertent human intruder, the 1995 BTP introduced two exposure scenarios that assess the possible dose consequences to an inadvertent human intruder from the handling of a discrete LLRW item 500

[1]The following corrections should be made to the May 1983, Technical Position: (1) p.1 first para., fourth line—delete the words, "or processor"; and (2) p.6, fourth line and p.12, second para., fifth line—replace "biannual" with "biennial."

years after disposal. The results from the technical analysis of the two handling scenarios are the basis for the Table A values and the Position on Encapsulation of Sealed Sources and Other Solid LLRW in this BTP.

This BTP replaces the 1995 BTP on Concentration Averaging and Encapsulation, and was written to improve clarity and ensure a more uniform interpretation of NRC's guidance. The 1995 BTP provided separate guidance for classifying (1) activated metals, (2) contaminated materials, and (3) cartridge filters. This rewrite of the BTP does not provide separate guidance for activated metals, contaminated materials and cartridge filters. For a given situation this BTP offers uniform guidance, regardless of whether the waste type is activated metals, or contaminated materials or cartridge filters. Although formatted differently, this version of the BTP does not change any of the guidance provided in the 1995 BTP**.**

This guidance is not intended to address all unique waste types or waste packaging methods, and other provisions for the classification of these specific wastes or waste mixtures may be deemed acceptable, as discussed under Section 12, "Alternative Provisions."

3. Organization of the BTP

The following paragraphs provide guidance on a subset of acceptable classification or encapsulation practices. Other provisions for classification or encapsulation of specific waste may also be deemed acceptable, as discussed in Section 12, "Alternative Provisions."

To improve clarity, a flowchart of the BTP's guidance has been prepared and is presented in Figures 1 and 2. The Figure 1 flowchart addresses the classification of mixtures of wastes in a single waste container. If a waste mixture is radiologically heterogeneous and the heterogeneity of the mixture exceeds established limits, the more highly concentrated item(s) should be removed from the mixture and classified as discrete items using the process shown in Figure 2. After removal of the more concentrated items, the remaining mixture must be reevaluated using Figure 1. Once the heterogeneity of the mixture is brought within limits established in this BTP, the mixture can be classified based on the average concentration of all items in the mixture. Figure 2 also provides guidance for the classification of wastes originating from liquids.

4. Initial Waste Classification

Waste classification requires information about the volume and concentration of each nuclide in each item of waste. The May 1983 Technical Position provides guidance on determining nuclide concentrations. Guidance on how to measure the volume of the waste for the purposes of classification is presented in Section 8 of this BTP, "Measuring Waste Volumes."

In general, the volume and nuclide concentration information about each individual item of waste must be sufficient to allow classification of that item as described in §61.55. If an item or a mixture of items contains more than one nuclide listed in Table 1 or in Table 2 of §61.55, the volume and nuclide information must be used to calculate the "sum of fractions," as explained in

61.55(a)(7). If the sum of fractions exceeds 1 for the Table 1 values or exceeds 1 for the column 3 of the Table 2 values, then the mixture exceeds the Class C limits and the licensee should determine if the mixture can be reconstituted to bring the sum of fractions below 1.

Assuming that the sum of fractions for a mixture does not exceed 1 (for Table 1 or column 3 of Table 2), the first decision (decision node A) in Figure 1 is whether the disposal container holds a single item or multiple items. Classification of an individual item is addressed in Section 7 of this BTP, "Classifying Individual Discrete Items." A container of solidified or absorbed liquid is considered a single item. The next decision (node B) is whether all items in the mixture are of a similar waste type. Similar waste types are wastes that have similar physical properties. A drum containing pieces of activated stainless steel is an example of a container of wastes that are of a similar waste type.

An example of a container of dissimilar waste types is a drum containing miscellaneous trash mixed with pieces of activated stainless steel. If the disposal container holds a mixture of dissimilar waste types, and the highest waste classification of any individual item of the mixture is not higher than the waste classification to the total mixture (average of the total activity over the total volume or mass), then the classification based on the average concentration may be used (node E). This provision does not apply to small concentrated microcurie sources (<3.7 MBq (100 µCi)) of waste such as check sources or gauges that may be mixed with contaminated trash waste streams. A container of dissimilar waste types that does not meet one of these two critera needs to be reconfigured, or the licensee can petition to classify the mixture under Section 12, "Alternative Provisions."

If the container holds multiple items of the same waste type, the next decision (node C) is whether the waste is radiologically homogeneous or not. Guidance on identifying and classifying homogeneous wastes is presented in Section 5. Guidance for classifying radiologically heterogeneous mixtures of similar waste types is presented in Section 6 and at the end of Section 5.

5. Classifying Homogenous Waste Types and Mixtures of Homogenous Waste Types

A radiologically homogeneous waste is one in which the radionuclide concentrations are likely to approach uniformity in the context of the intruder scenarios used to establish the values included in Tables 1 and 2 of 10 CFR 61.55. Certain waste streams may be radiologically homogenous and these streams are titled*homogeneous waste types.* Homogenous waste types include, for example, spent ion-exchange resins, filter media, solidified liquid, evaporator bottom concentrates, or contaminated soil. Because homogenous waste types have soil-like properties, the radionuclides in these waste streams would be uniformly distributed when exhumed under the discovery or construction scenario as described in the EIS supporting Part 61.

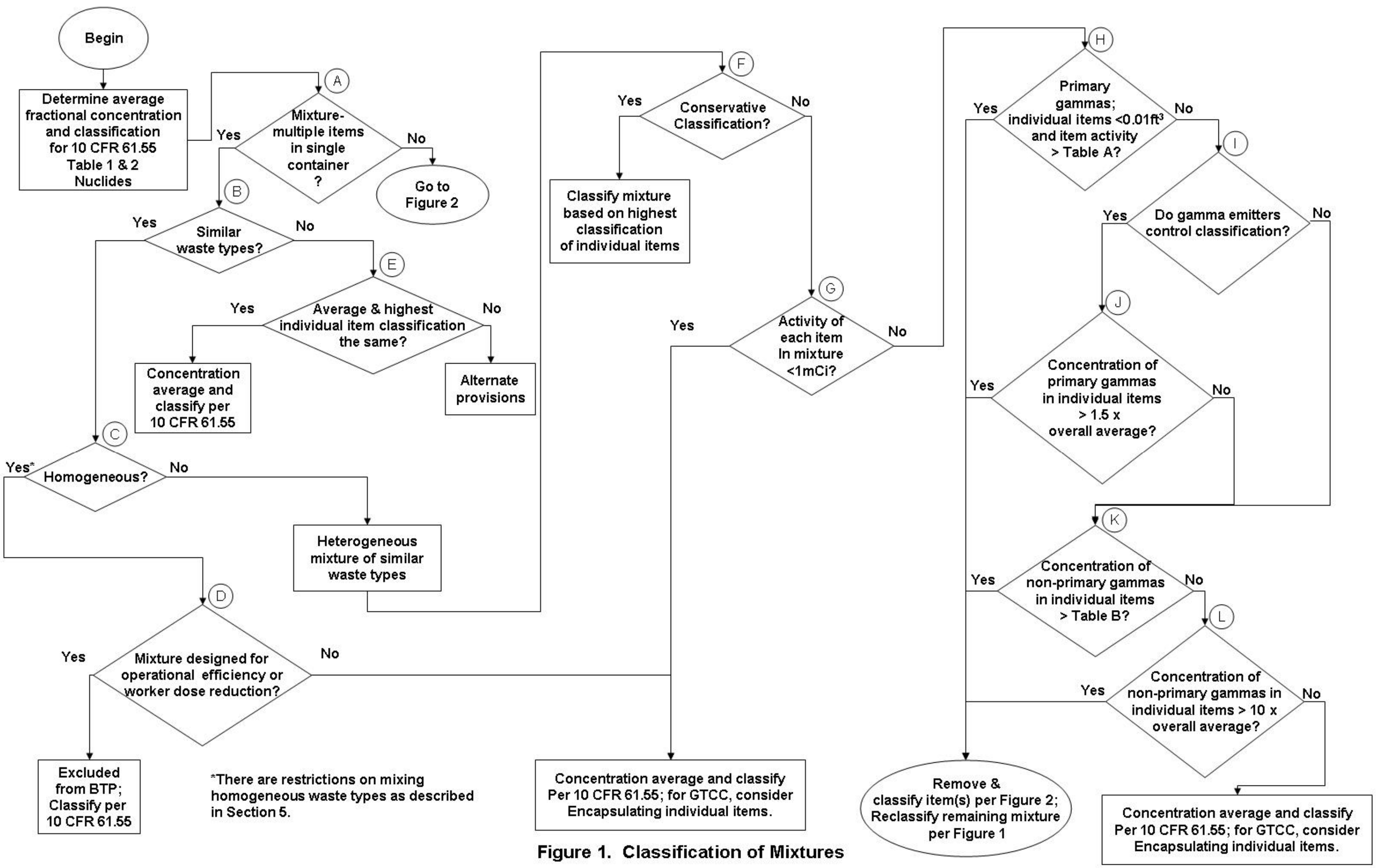

Figure 1. Classification of Mixtures

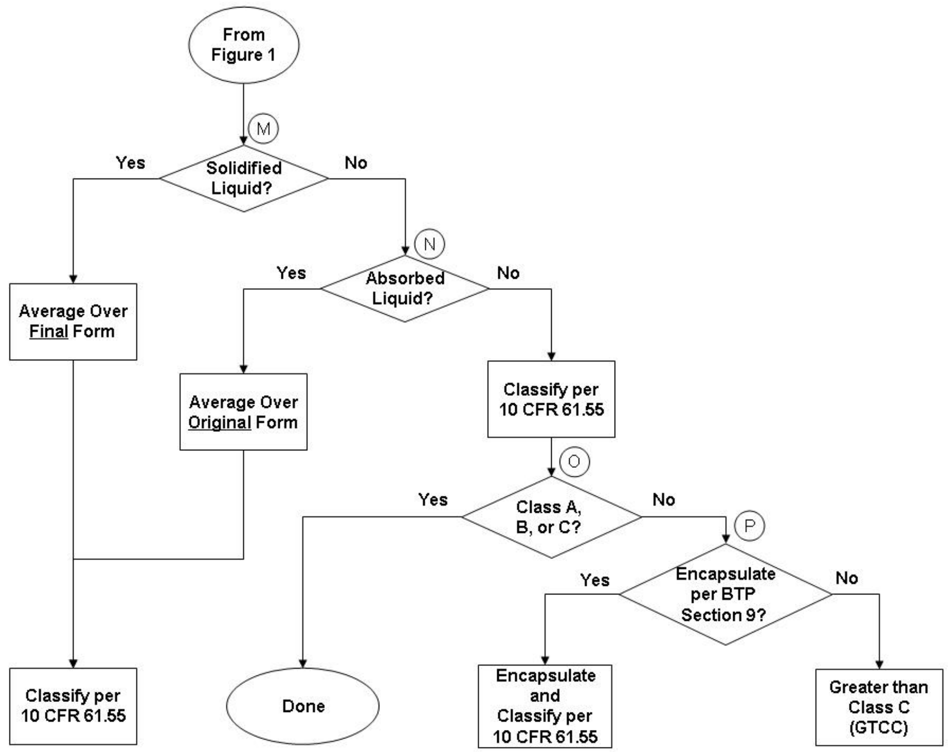

Figure 2. Classification of Individual Items

Contaminated trash waste, which may be composed of a variety of miscellaneous materials, may be considered homogeneous for purposes of waste classification when placed in containers. To the extent that contaminated trash and contaminated soil are packaged in a disposal container to achieve ≥90% fill, the volumetric-averaged concentration of radionuclides in these waste types can be based on the fill-volume of the container. Alternatively, the volume of the waste can be calculated from the weight of the container contents divided by the density of the contents. A representative density, based on a representative distribution of materials as they occur in waste, may be used.

A homogenous waste type may be volume-averaged or weight-averaged per §61.55(a)(8). Two or more similar homogenous waste types (e.g., spent ion-exchange resin or contaminated soil) may be mixed together, provided: the classification of the mixture, using the sum of fractions rule specified in 10 CFR 61.55, should be based on either: (a) the highest nuclide concentrations in any of the individual waste types contributing to the mixture; or (b) the volumetric- or weight-averaged nuclide concentrations of the mixture; provided that the concentrations of the individual waste type contributors to the mixture are within a factor of 10 of the average concentration of the resulting mixture.

A designed collection of homogeneous waste (node D) from a number of sources within a licensee's facility, for purposes of operational efficiency or occupational dose reduction, is not considered "mixing," and is exempt from this BTP guidance.

If a waste container holds a mixture of similar waste types that are not radiologically homogeneous (node C), proceed to Section 6, "Classifying a Heterogeneous Mixture of Similar Waste Types."

6. Classifying a Heterogeneous Mixture of Similar Waste Types

This section addresses the classification of a container of radiologically heterogeneous items of a similar waste type.

6.1 Conservative Classification Based on Highest Individual Item

The next decision (node F) is whether a mixture will be conservatively classified according to the item in the mixture with the highest classification. One may always classify a heterogeneous mixture conservatively based on the highest classification of any individual item in the mixture. Thus, if a mixture of items in a waste drum includes a single item classified as Class C based on 10 CFR 61.55, and the remaining items are classified as Class A, the entire waste drum may be conservatively classified as Class C.

If each item in the mixture has an activity less than 1 mCi (node G), the mixture may be concentration-averaged and classified per 10 CFR 61.55.

If the mixture can not be conservatively classified or averaged because of high activity (>1 mCi per item), the mixture must be screened to ensure that the radiological heterogeneity is not too extreme. Section 6.2 and 6.3 describe the screening criteria for classifying heterogeneous mixtures of similar waste types. The appendix to this BTP provides justification for the screening or "smoothing" criteria presented in Sections 6.2 and 6.3.

6.2 Averaging Involving Primary Gamma-Emitters

As used in this BTP, the "primary gamma-emitting" nuclides are Co-60, Nb-94, and Cs-137/Ba-137m. If (1) the volume of any item in the mixture is less than 0.01 ft^3, and (2) the activity of the small individual item or items exceeds the values shown in Table A (node H), the item or items should be removed and treated as individual discrete items per Figure 2. Such items are similar to sealed radioactive sources and should be managed individually.

Table A. Activity Levels of Primary Gamma Emitters in Individual Items Potentially Requiring Their Piecemeal Consideration in Classification Determinations

Nuclide	For Waste Classified as Class A or B	For Waste Classified as Class C
Co-60	>26 TBq (700 Ci)	N.A.
Nb-94	>37 MBq (1 mCi)	>37 MBq (1 mCi)
Cs-137/Ba-137m	>111 MBq (3 mCi)	>1.1 TBq (30 Ci)

After these items have been removed, the remaining mixture is further evaluated for radiological homogeneity. If the primary gamma-emitters control the classification of the mixture (node I), and if the concentration of a primary gamma-emitting nuclide in any item of the mixture is greater than 1.5 times the overall average concentration of the mixture for that nuclide, that item should be removed and treated as an individual discrete item per Figure 2 (node J). This factor of 1.5 does not apply if the classification of the mixture, as a result of radionuclides other than primary gamma-emitters, is higher than the class derived from the primary gamma emitters.

6.3 Averaging Involving Radionuclides Other Than Primary Gamma-Emitters

As used in this BTP, "radionuclides other than primary gamma-emitters" are H-3, C-14, Ni-59, Ni-63, and alpha-emitting TRU with half-lives greater than 5 years (other than Pu-241 and Cm-242). If any item in the mixture exceeds the values shown in Table B (node K), these items should be removed and treated as individual discrete items per Figure 2. The remaining mixture is further evaluated for radiological homogeneity (node L) using the following criterion.

The concentrations of all 10 CFR 61.55-tabulated radionuclides in the disposal container, other than the primary gamma-emitters, may be based on the volumetric- or weight-averaged concentrations of the combined materials if the concentrations of classification-controlling individual nuclides in individual waste items are within a factor of 10 of their respective averages over all items in the mixture. A classification-controlling nuclide is a nuclide in the waste in concentrations greater than 1% of the concentration of that nuclide listed in Table 1, or greater than 1% of the applicable class-dependent concentration of that nuclide in Table 2, Column 2 or 3 of 10 CFR 61.55. Note that a nuclide may be significant for reporting purposes under Section 4 in the May 1983 Technical Position and yet not be a classification-controlling nuclide.

Individual items whose concentration exceeds 10 times the average concentration of that nuclide in the mixture should be removed and treated as individual discrete items per Figure 2. If the concentration of all remaining nuclides listed above are less than 10 times the average concentration of those nuclides in the mixture, classification may be made on the basis of concentration averaging as described in 10 CFR 61.55(a)(8).

Table B. Activity Levels of Radionuclides other than Primary Gamma Emitters in Individual Items Components Requiring Their Piecemeal Consideration in Classification Determinations

Nuclide*	For Waste Classified as Class A or B	For Waste Classified as Class C
H-3	>0.3 TBq (8 Ci)	N.A.
C-14	>0.04 TBq (1 Ci)	>0.4 TBq (10 Ci)
Ni-59	>0.15 TBq (4 Ci)	>1.5 TBq (40 Ci)
Ni-63	>0.26 TBq (7 Ci)	>55 TBq (1500 Ci)
Alpha emitting TRU with half-life greater than 5 years (excl. Pu-241 and Cm-242)	>111 MBq (3 mCi)	>1110 MBq (30 mCi)

* Other nuclides listed in the tables in 10 CFR 61.55 are not expected to be of importance in determining waste classification.

7. Classifying Individual Discrete Items

Figure 2 provides guidance for classifying individual discrete items. For individual discrete items, which originated from liquid wastes (node M), classification is made on the basis of concentration averaging as described in 10 CFR 61.55(a)(8). However, a distinction is made (node N) between solidified liquids and absorbed liquids in choosing the basis for volume or weight averaging. For solidified liquids, averaging is made over the volume or weight of the final waste form. For absorbed liquids, averaging is made over the original volume or weight of the liquid before being absorbed on a substrate.

For individual discrete items other than those originating from liquid forms, the individual items are first classified (node O) in accordance with 10 CFR 61.55. If this determination finds that individual items exceed Class C activity concentrations and are therefore not generally acceptable for near-surface disposal, one may establish, following the guidance in Section 9, if the item can be encapsulated and the concentration averaged over the final waste form to a value less than the Class C upper limit (node P). If the encapsulated item and the encapsulated media have an average concentration above the Class C limit, the individual item is classified as Greater-Than-Class-C (GTCC) LLRW.

8. Determining the Concentration and Volume of the Waste

The May 1983 Technical Position provides NRC's guidance for determining nuclide concentrations and Table C provides guidance for determining waste volumes.

Table C. Volume and Mass for Determination of Concentration

Waste Type	Allowable Classification Volume or Mass
Contaminated trash or soil	Reasonable fill volume of container or mass of waste (<10% void)*
Absorbed liquids	Volume or mass of liquid before absorption
Solidified liquids	Volume or mass of solidified mass
Solidified ion-exchange resins	Volume or mass of solidified mass**
Dewatered ion-exchange resins in High-Integrity Containers (HICs) or liners	Displaced (bulk) volume of waste (interstitial space may be included) or dewatered mass of ion-exchange resins
Filter cartridges in HICs or liners	Displaced volume (interstitial volume may be included) or envelope volume or mass of filters*
Activated components, components containing radioactivity in their design, or contaminated materials	Full density volume/(major void volumes subtracted from envelope volume) or mass of components*
Encapsulated filter cartridges or sealed sources	Volume or mass of solidified mass when encapsulated in accordance with the guidance provided in this Position
* Mixtures of waste streams subject to additional guidance defined in Section 5. **If homogeneity is maintained in the solidified mass.	

9. Position on Encapsulation of Sealed Sources and Other Solid Low-Level Radioactive Wastes

Encapsulation can mitigate waste dispersion, provide additional shielding to limit external radiation, and satisfy the stability requirement of 10 CFR 61.56(b) and technical requirements for land disposal facilities of 10 CFR 61.52(a).

The amount of credit allowed for encapsulation should be limited so that extreme measures cannot be taken solely for the purposes of dilution. To be consistent with the NRC's policy on volume reduction and to limit extremely large "point sources" of radioactivity in the disposal site, generally acceptable values for minimum and maximum encapsulated waste volume and mass, nuclide activities, and radiation levels are established.

These generally acceptable bounding conditions are as follows:

(1) The minimum solid volume or mass used to encapsulate should be sufficient to make handling the radioactive waste by an inadvertent intruder prohibitively difficult. The size or weight of the encapsulated radiation source should be enough to preclude movement without the assistance of mechanical equipment.

(2) The maximum solidified volume or mass used to encapsulate a single discrete source should be 0.2 m^3 or 500 kg (the volume and filled weight of a typical 55-gallon drum). Larger volume and mass may be used for encapsulating single sources, but only 0.2 m^3 or 500 kg should be used to determine waste concentrations, unless a rationale is provided. Encapsulation of multiple sources in larger volume may be considered acceptable under Section 12, "Alternative Provisions," of this BTP.

These bounding volumes and weights will ensure that the potential radiological impacts from encapsulated, single discrete sources are within the range of impacts that would be calculated if the radioactivity were homogeneously distributed throughout the encapsulating media.

Other requirements for encapsulation are:

(3) The maximum amount of any radionuclide that should be encapsulated in a single disposal container should not exceed the maximum concentration limits for Class C waste, as defined in Tables 1 and 2 of 10 CFR 61.55, when averaged over the waste and the encapsulating media.

(4) The maximum gamma-emitting radioactivity (e.g., from Cs-137/Ba-137m, Nb-94) acceptable for encapsulation is that which would result in a dose rate of less than 0.2 µSv/hr (0.02 mrem/hr) on the surface of the encapsulating medium after decaying for 500 years. The radiation attenuation provided by the encapsulating medium should not exceed that provided by 15 inches of concrete. Furthermore, the maximum Cs-137/Ba-137m gamma activity acceptable for encapsulation in a single disposal container is 1.1 TBq (30 Ci) at the time of disposal.

(5) In all cases when a discrete source of radioactive solid waste is encapsulated, written procedures should be established to ensure that the radiation source(s) is reasonably centered within the encapsulating medium.

10. Quality Assurance Program

In accordance with Appendix G of 10 CFR 20, the licensee classifying the waste must have in place a quality assurance program to ensure compliance with the waste classification provisions of 10 CFR 61.55. As part of this quality assurance program, if the classification of a mixture is based on the volumetric- or weight-averaged nuclide concentration of a mixture, the licensee responsible for classification of the waste should prepare, retain with manifest documentation, and have available for inspection, a record documenting the licensee's waste classification analysis. It is generally expected that this record or analysis, in and of itself, should be sufficient to show that the mixing was undertaken under the provisions of this BTP.

11. Waste in High-Integrity Containers

For wastes stabilized by emplacement within High-Integrity Containers (HICs), the volume or weight used to determine classification should be based on the displaced volume or weight of the waste itself, rather than the gross volume or weight of the HIC.

12. Alternative Provisions

Under 10 CFR 61.58, the Commission, on request, may authorize other provisions for the classification and characteristics of waste on a specific basis if, after evaluation of the specific characteristics of the waste, disposal site and method of disposal, it finds reasonable assurance of compliance with the performance objectives in Subpart C of 10 CFR Part 61.

Alternatives to the determination of radionuclide concentrations for waste classification purposes, other than those defined in this technical position, may be considered acceptable. For example, the physical form of certain discrete wastes (e.g., activated metals) may be such that intruder exposure scenarios, other than those used to establish the values in Tables 1 and 2 of 10 CFR 61.55, may be appropriate. A case in point could be the disposal of a large intact activated component filled with a structurally stable medium (e.g., cement), or enclosed in a massive robust container capable of meeting structural stability requirements. A request that demonstrates, with reasonable assurance, that the performance objectives in Subpart C of 10 CFR Part 61 are met, may be used to justify that the waste is acceptable for near-surface disposal.

13. References

U.S. NRC, 1981, "Draft Environmental Impact Statement on 10 CFR Part 61, 'Licensing Requirements for Land Disposal of Radioactive Waste'," NUREG-0782, September 1981.

U.S. NRC, 1982, "Final Environmental Impact Statement on 10 CFR Part 61 'Licensing Requirements for Land Disposal of Radioactive Waste'," NUREG-0945, November 1982.

U.S. NRC, 1983, "Final Waste Classification and Waste Form Technical Position Papers," dated May 11, 1983. (Was this published in the *Federal Register?)*

U.S. NRC, 1995, "Branch Technical Position on Concentration Averaging and Encapsulation," dated January 17, 1995, *Federal Register,* Vol. 60, No. 14, p. 4451.

Appendix - Technical Basis for Concentration Averaging and Encapsulation Guidance for Classification of Discrete (Heterogeneous) Wastes[2]

Background

This BTP on Concentration Averaging and Encapsulation provides guidance for the disposal of discrete items or mixtures of such items that fall within the "envelope of safety" defined in the environmental impact statement (EIS) supporting 10 CFR Part 61. The primary consideration in developing the guidance for disposal of discrete items and wastes was to ensure that the potential doses to an inadvertent human intruder from exhuming a discrete item or waste would be equivalent to the potential doses to an intruder from exposure to the "contaminated soil," as described in the EIS supporting Part 61.

Application to disposal of gamma-emitting sealed sources

This BTP provides separate guidance for: (1) primary gamma-emitters (Co-60, Nb-94, and Cs-137/Ba-137m), and (2) radionuclides other than primary gamma emitters. This subdivision was considered necessary because "hot spots" of gamma activity may be more significant to potential intruder doses than hot spots associated with the other nuclides.

The concentration values in Tables 1 and 2 of §61.55 are based on potential doses to an inadvertent intruder, as discussed in the EIS supporting Part 61. Those intruder dose calculations included a scenario in which the intruder resides on a closed disposal site and inadvertently exhumes LLRW. This exhumed waste was assumed to be indistinguishable from soil and, as a result, the intruder would have been unaware of his or her interaction with the LLRW.

In this Part 61 EIS scenario, the processes of exhuming and moving the materials could mix the wastes with clean interstitial and cover material, reducing the "as disposed" concentration of radioactive material by an estimated factor of about 8.

The dose rate could be reduced by an additional factor of about 10 to account for the reduced likelihood of intrusion, the fact that not all of the wastes would be at the full Class C limit, and the fact that any initially encapsulated waste would be homogenized over a soil volume equivalent to the encapsulating medium. Taken together, the annual intruder dose would thus be reduced by a factor of 80.

The dose criterion for the primary gamma-emitting nuclides, from which the Table 1 and 2 concentration values of §61.55 are derived, is 500 mrem/year. This is the projected dose that an intruder would be calculated to receive if waste were exhumed and dispersed according to the EIS intruder-agricultural scenario. That is, for Cs-137 disposed at the Class C upper bound concentration of 4600 Ci/m^3 and exhumed 500 years after disposal, and considering concentration reduction factors and radioactive decay, the intruder would be exposed to an infinite half-plane source of Cs-137 at a concentration of about 540 pCi/m^3 (or 340 pCi/g). The calculation that yields this result is:

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[2] Except as noted, the details presented in this Technical Basis are unchanged from the Technical Basis presented in the 1995 BTP; however the text has been modified to improve clarity.

For Cs-137, $t_{1/2}$ = 30 years and $\lambda = \ln 2/ t_{1/2} = 0.0231$

Decay factor $\exp(-\lambda t) = \exp(-.0231 \times 500) = 9.64 \times 10^{-6}$

Interstitial and cover mixing factor = 0.125 (factor of 8)

Intrusion likelihood and mixing factor with lower activity waste = 0.10 (factor of 10)

Then:

$(4600\ \text{Ci/m}^3 \times 10^6\ \text{pCi/cm}^3/\text{Ci/m}^3) \times (9.4 \times 10^{-6}) \times (0.125) \times (0.1) = 540\ \text{pCi/m}^3$ or

$340\ \text{pCi/g} @ 1.6\ \text{g/cm}^3$.

An intruder exposed to this infinite 1-m thick half-plane source at a concentration of 540 pCi/m^3 would receive a dose of about 500 mrem in a year, presuming (from the EIS for Part 61) a scenario-equivalent unshielded exposure of about 2360 hours/year.

The basis for the BTP encapsulation policy is to ensure that the dose from exposure to a discrete item is within the envelope of safety defined in the EIS for Part 61. Therefore, the exposure to a discrete item for 2360 hours/year should not result in a dose exceeding that caused by the intruder-agricultural exposure scenario used in the Part 61 EIS. Two principal scenarios related to the inadvertent handling of a discrete item of LLRW were used to set the technical basis for concentration averaging and encapsulation:

> Gamma Sealed Source Handling Scenario (1): At 500 years, exposure to the *encapsulated* sealed source should result in the same maximum dose as the agricultural scenario, 500 mrem/year, even if scenarios other than the intruder-agricultural (e.g., handling) are considered.[3]
>
> Gamma Sealed Source Handling Scenario (2): If the source is exhumed in its encapsulated state, the intruder should not receive an exposure greater than 500 mrem/year, recognizing that the intruder could be exposed to other exhumed waste or other sealed sources.

Scenario (1) presumes that the intruder's exposure is bounded by a one meter distance from the *encapsulated* source for a period of 2360 hours/year 500 years after disposal. At 500 years after disposal, a Cs-137/Ba-137 source with activity 1.1 TBq (30 Ci) will have decayed to 1.1×10^{-5} TBq (about 300 μCi). The dose rate outside the 15 inches of encapsulating concrete from a 1.1×10^{-5} TBq source at the center of the container is calculated to be about 0.2 mrem/hr, or about 472 mrem over 2360 hours.[4]

Scenario (2) assigns a dose rate of 50 mrem/year or 0.02 mrem/hr for 2360 hours to the surface of the encapsulated sealed source. This factor of 10 reduction in the dose criterion (from 500 mrem/yr to 50 mrem/yr), and the point of measurement, were incorporated into the analysis to account for exposure of the intruder to different scenarios and to additional exhumed waste containing the same radionuclide. Credit is taken for the 15-inch shielding of the encapsulating material in a 55 gallon drum, but not for the structural integrity. Under these constraints, the

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[3] There is an apparent typographical error in the 1995 BTP. The 1995 BTP states that Scenario (1) is based on an unencapsulated Cs-137 source at 1 m for 2360 hours. Such a scenario would result in a calculated dose of about 9.1 rem at 2360 hours. It is believed that the 1995 authors intended to say the dose from an *encapsulated* source, and the text of this revised BTP has been changed to state that the Cs-137 sources in Scenario (1) was encapsulated.

[4] This calculation was done with the Microshield code.

activity of an encapsulated Cs-137 source could be about 300 μCi at 500 years or 30 Ci at the time of disposal.[5]

Since both the above scenarios result in approximately the same source activity constraint, and no practical reason could be put forward to justify selection of a higher criterion, the technical position includes a 30 Ci bound on the activity of a Cs-137/Ba-137m sealed source that can be encapsulated and disposed of as Class C waste in a near-surface disposal facility. This 30 Ci Cs-137/Ba-137m limit for a discrete encapsulated source is within the "envelope of safety" defined in the EIS supporting 10 CFR Part 61. If applied to a point source of Nb-94, the activity constraint both at disposal and at 500 years would be about 40 μCi due to the differences in the dose conversion factors of Cs-137/Ba-137m and Nb-94.

Disposal of alpha/beta emitting sealed sources

Potential exposures from the exhumation of alpha or beta emitting nuclides would involve either ingestion or inhalation of these nuclides by the intruder, who would either breathe resuspended material or ingest material from contaminated foodstuffs. Neither of these pathways depends on localized hotspots as long as the average concentration over a large area is unaffected. Therefore, the inventory of alpha- and beta-emitting sealed sources is constrained by those source activities, that when averaged over the weight or volume of the encapsulated source (typically a 55 gallon drum), would lead to concentrations acceptable under the §61.55 concentration criteria. The largest activity of a transuranic nuclide, other than Pu-241 and Cm-242, that is generally acceptable for encapsulation in 0.2 m^3 is about 1.1 GBq (30 mCi), presuming the density of the encapsulating mass in 1.3 g/cm^3. For determining mass-based concentrations, it is generally acceptable to take credit for the actual density of the material if the density is less than 2.2 g/cm^3.

Disposal of primary gamma-emitters in activated materials or metals, or components incorporating radioactivity in their design

The guidance on these items evolves from the "sealed source" position. The possibility of exhumation at 500 years of sealed sources with activities typically ranging from 40 to 300 μCi was discussed above. If the same gamma-emitting activity were exhumed in the form of discrete activated materials or metals, or components incorporating radioactivity in their design, the hypothetical intruder would probably not sustain a dose greater than that calculated from the sealed sources because of the typical distribution of the activity over a larger volume and in materials that may exhibit a degree of self-shielding. Although these "dose reduction" aspects cannot be quantified, it is reasonable to allow 1 mCi of gamma emitting nuclide in any exhumed piece of discrete waste, as long as the activity of the nuclide averaged over the waste volume in the disposal container complies with the appropriate §61.55 concentration value.

The rationale in the preceding paragraph is used to construct Table A. For Table A, 1 mCi, and not 40 μCi from the sealed source calculation, was used as the limit for Nb-94. Items that are smaller than 0.01 ft^3, that exceed the Table A values, should be considered individually, for the purpose of waste classification. The tabulated values ensure that 100 years after disposal of Class A and B waste or 500 years after disposal of Class C waste, an intruder would not interact

[5] The number resulting from the back-calculation from 0.02 mrem/hr is 281 μCi after 500 years, or 29 Ci emplaced.

with more than 1 mCi of gamma-emitting activity in activated material or metal or in a component containing this radioactivity in its design.

Since sealed sources, activated materials or metal, or components containing radioactivity in their design may be disposed of in the same disposal container with other waste of similar type containing the same gamma-emitting nuclide, acceptable concentration averaging guidance is included for these situations. One can always classify the contents of a disposal container based on the highest classification of any specific item in the container. Averaging is also acceptable if the concentration of each primary gamma-emitting nuclide in each discrete item in the disposal container is within a factor of 1.5 of the average concentration of each primary gamma-emitting nuclide in the container. This factor of 1.5 precludes "hot spots" in gamma-emitting waste from significantly affecting projected intruder doses irrespective of whether the intruder is exposed through the intruder-agricultural scenario or through direct interactions with discrete waste (e.g., handling scenarios). For example in 5.6 m^3 of containerized waste, 2.24 m^3 could contain 0.3 Ci/m^3 of Nb-94 if the remaining waste contained Nb-94 at a concentration of 0.133 Ci/m^3. If the higher activity piece(s) were all exhumed and assumed to be at the surface of the disposal facility, the dose rate at 1 meter from the center of this piece(s) would be about 6 mrem/hr (e.g., assuming a circular piece of metal with a radius of 3.34 m and a thickness of 0.0635 m (e.g., a circular piece of steel plate)). Considering an appropriate discovery or construction scenario as described in the EIS supporting 10 CFR 61, a projected dose to an intruder would not be expected to exceed 500 mrem/year.

Disposal of alpha/beta emitters (nuclides other than primary gamma-emitters) in activated materials or metals, or components incorporating radioactivity in their design

The guidance on classifying items containing other than the primary gamma-emitters, also reflects the "sealed source" position described above. In this case, the Position defines a "mixing" constraint that is within the context of the general waste classification rationale expressed in the documentation that supported the Part 61 regulation. In defining this constraint, it was noted that the §61.55 concentration values that delineate the boundaries between different waste classes (i.e., A, B, C, and Greater-than-Class C (GTCC)) typically differ by more than one order of magnitude. Also, as noted previously, the potential dose to an intruder from alpha/beta activity, or the small quantities of gamma activity associated with nuclides other than Co-60, Nb-94, and Ca-137/Ba-137m, is essentially independent of localized "hot spots." As a result, the guidance in this Position allows concentration averaging of the alpha/beta emitting activity in individual items if all the concentrations in the individual items within a disposal container are within an order of magnitude (a factor of 10) of the average concentration over all items in the container.

The rationale in the preceding paragraph is used to construct Table B in the Position, which applies to situations in which larger components require sectioning as a result of operational considerations. Since any potential intruder dose is essentially independent of alpha/beta (or non-primary gamma-emitter) "hot spots," the numerical values in the table reflect the maximum activity that would be allowed if the activity was contained in a sealed source encapsulated in a 0.2 m^3 drum, and a minimum volume criterion is not necessary. As an example of this, the 61.55 Class C limit for Ni-59 is 220 Ci/ m^3; the maximum activity allowed in a 0.2 m^3 drum is therefore 220 x 0.2 = 44 Ci, comparable to the 40 Ci shown in Table B.