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DOE STANDARD

Standard for Communicating Waste Characterization and DOT Hazard Classification Requirements for Low Specific Activity Materials and Surface Contaminated Objects

[This Standard describes acceptable, but not mandatory means for complying with requirements. Standards <u>are not</u> requirements documents and <u>are not</u> to be construed as requirements in any audit or appraisal for compliance with associated rule or directives.]

U.S. Department of Energy
Washington, D.C. 20585

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BACKGROUND

The Office of Environmental Management, in coordination with other program offices, waste certification officials, and transportation managers, developed this standard to provide a uniform, standard methodology to ensure collection and documentation of information needed to properly characterize, classify, and identify candidate low specific activity (LSA) material and surface contaminated objects (SCO) for shipping operations compliant with the U.S. Department of Transportation (DOT) regulations. This document highlights the need to clearly document and communicate information needed to ensure radiological characterization data is sufficient to determine the radionuclide activity distribution within and/or on objects that can potentially be identified as LSA material or SCO. The standard focuses solely on low-level radioactive waste and does not address other types of radioactive material which may be determined to be LSA or SCO. This standard emphasizes the importance of early project coordination and documentation of methods used to make LSA/SCO determinations.

DOE Manual 435.1-1, *Radioactive Waste Management Manual*, requires using direct or indirect methods to characterize low-level waste. The characterization shall be documented in sufficient detail to ensure safe management and compliance with the nuclear safety requirements at the facility where the waste was generated as well as the waste acceptance requirements of the facility receiving the waste. Meeting the facility's waste acceptance criteria for treatment, storage, and disposal is based on the activity/mass of the waste without consideration of how the radionuclides are distributed within the matrix, or the configuration of objects in the waste and radioactive contamination distribution on their surfaces.

The DOT requires using the criteria identified in the Hazardous Materials Regulations and the provisions of the Hazardous Materials Table to assign a hazard class for the hazardous material.[1] To efficiently move larger amounts of waste material in bulk, most waste shipments from nuclear fuel cycle facility decommissioning and cleanup, remediation, and decontamination projects may be further grouped as LSA material or SCO shipments. The DOT requirements for LSA material are based on the assumption that the radionuclides are distributed within the waste matrix; the DOT criteria for SCO are based on the assumption that the radionuclides are distributed on the surfaces of a non-radioactive object. The information received from the waste acceptance criteria characterization may need to be supplemented (e.g., distribution of the radionuclides within the matrix, radioactive contamination distribution on the surface of objects) to determine if the waste meets LSA material or SCO definitions.

It is important to understand the DOT Hazardous Materials Regulations and the DOT/U.S. Nuclear Regulatory Commission (NRC) jointly published standard, "Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects."[2] The DOT/NRC standard addresses areas of uncertainty arising from revised regulations that separated SCO from LSA materials and provides methods for demonstrating compliance that are acceptable to the DOT and NRC. DOT hazard classification methods, other than those stated herein, may be found acceptable with adequate justification and supporting documentation.

[1] Hazardous Materials Regulations are the regulations at 49 CFR parts 171 through 180

[2] NUREG-1608 (DOT Reference RAMREG-003)

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1.0 TYPES OF CANDIDATE LSA MATERIALS AND SCO

Although other types of radioactive material and waste may be candidate LSA material or SCO, this standard focuses solely on low-level waste (LLW)[3]. The DOE ships various types of radioactive waste stemming from current and historical operations. Generally, candidate LSA material and SCO within the DOE complex are wastes generated from the clean-up and deactivation of World War II and Cold War era nuclear processing and weapons support operations. These waste matrices can be complex. The level of effort required to characterize waste varies based on the type and origin of waste being generated. Some common waste generation sources include:

- Process Related (known/managed wastes)
- Accidents (spill cleanups)
- Environmental Restorations
    a) Simple (e.g., soils)
    b) Complex (e.g., former burial grounds)
    c) In Situ (see Process Related)
- Deactivation, Decontamination, and Decommissioning
    a) Internal Processes (e.g., piping, tanks, gloveboxes, valves, pumps)
    b) Internal Support (e.g., wiring, sanitary plumbing, duct work, framework)
    c) Structures (e.g., buildings)
- Pre-containerized Wastes

A single, DOE-complex-wide system to characterize waste for proper management, facility acceptance, and packaging and transport is impractical; the criteria applied by each area differ such that independent assessments shall be completed against each governing requirement. Each waste generation activity shall be viewed separately and a waste characterization methodology prepared to adequately address chemical, radiological, and physical parameters of what may be expected. The characterization methodology shall be able to consider waste anomalies that may arise during waste characterization. Thus, varying methodologies may be needed to perform characterization based on the waste being considered. Because a single system for characterization is non-existent, early project coordination is essential for the characterization and hazard classification of waste. Two assumptions have been incorporated into the preparation of this document:

[3] Radioactive waste not classified as high-level waste, transuranic waste, spent nuclear fuel, or by-product tailings containing uranium or thorium from processed ore (as defined in Section 11(e)2 of the Atomic Energy Act of 1954 [42 U.S.C. 2011 et seq.]), and not classified as hazardous waste under the Resource Conservation and Recovery Act. Test specimens of fissionable material irradiated for research and development only, and not for the production of power or plutonium, may be classified as LLW provided that the concentration of transuranics is less than 100 nanocuries per gram.

1. Some LLW will be transported offsite to an NRC licensed disposal facility and some transported to a DOE LLW disposal facility.
2. The methodologies applied for LLW characterization may be applied without regard to the final destination (i.e., NRC or DOE disposal facility).

2.0 PROJECT COORDINATION

It is very important to have all affected parties participating in early coordination and proper preparation before, and monitoring during waste cleanup activities. Thorough preparation helps minimize cost, time, personnel exposure (radiological and/or chemical), and other unwanted consequences associated with inadequate coordination. Many DOE sites use an interdisciplinary team (e.g., an Integrated Project Team) of nuclear safety, criticality safety, environmental, safety and health, facility, and security subject matter experts and health physicists to identify needs and requirements, review proposed projects and activities, and identify and resolve potential issues before and during the commencement of a project. Staff knowledgeable in DOT requirements shall plainly communicate anticipated complexities in hazard classification to DOT requirements, as well as packaging and shipping logistics during project coordination.

The operations during the generation and preparation of waste for eventual transport to a treatment, storage, or disposal facility affect the full characterization process. For example, prior to waste processing (e.g., compacting materials, shredding personal protective equipment) it may be more cost-effective to collect data (i.e., smears) needed to meet DOT definitions. After waste processing, it may be harder to gather the required data and a more costly classification and packaging option may be needed.

The management system defined at each site will affect how waste characterization and hazard classification is performed and who has the responsibility for each regulatory or facility requirement. Some waste operations rely on the Waste Certification Official (WCO) to verify the complete characterization to the waste acceptance criteria of the destined receiving facility, including the DOT hazard classification requirements. In settings where transuranic waste is generated (with potential for subsequent characterization as LLW), formal Visual Examination is performed as the waste is packaged or Real-time Radiography is performed after the waste is packaged. Given the need for radiological control during waste generation, some DOE sites use radiological engineering experts who have been trained in DOT hazardous materials regulations to complete the DOT hazard classification. Other waste operations assign the DOT hazard classification responsibility to an independent group responsible for shipping-related activities. For example, a waste generator may characterize waste to facility requirements then use in-field operations to package the waste based on the established Waste Acceptance Criteria (WAC) profile. The information about the packaged waste is given to a group responsible for offsite shipping. In this case, management shall determine if the waste generator or field operations personnel are responsible for ensuring all DOT hazard classification packaging requirements are met before the waste is packaged. Because the waste is packaged for offsite shipment before the personnel in the shipping group have performed DOT hazard classification, the waste generator, the WCO, or field operations group is responsible for ensuring waste subject to DOT Hazardous Materials Regulations is classified in accordance with the WAC and the DOT hazard classifications before the waste can be properly packaged. Before assigning responsibility for DOT hazard classification of waste, management may consider creating a diagram depicting the complete waste characterization and DOT hazard classification process, from initial point of generation of waste to final release for transport (see Appendix A). Assignment of responsibilities for completing actions identified on the diagram should include the identification of the person(s) who performs the DOT hazard classification, selects the appropriate packaging for storage and/or transport, and fills then closes the packaging. Each entity performing an activity in this process (e.g., classification of waste, packaging selection, filling, and closing) shall be a DOT hazardous materials employee who is subject to the training and testing requirements of 49 CFR 172 Subpart H.

3.0 RADIOLOGICAL WASTE CHARACTERIZATION

LLW destined for near surface disposal in the US shall be properly characterized using the given facility's WAC which, at a minimum, for NRC licensed disposal facilities, shall incorporate the NRC waste classification criteria, or DOE Order 435.1 when destined to a DOE LLW disposal facility.

Waste generated from DOE activities often contains contaminants regulated by varying Federal and state regulations. DOE M 435.1-1 requires implementation of a waste certification program to ensure that the waste acceptance requirements of facilities receiving LLW for storage, treatment, and disposal are met. The waste certification program designates the officials with the authority to certify and release waste for shipment. Characterization has to consider the various requirements and regulations as well as the treatment, storage, and disposal facility's WAC, when applicable.

When packaging and shipping waste that meets a DOT hazard classification criteria for off-site transport[4], the DOT Hazardous Materials Regulations provide the requirements for safe and secure transportation (including pre-transportation and transportation functions) of hazardous materials in commerce.[5]

The person who offers Class 7 (radioactive) material for transportation is responsible for ensuring the material is properly classified, described with hazardous material information clearly communicated, packaged, and in proper condition for transport as required in the Hazardous Materials Regulations. A

[4] Radioactive materials may be below DOT hazard class criteria but above DOE releasable limits per DOE-O 5400.5

[5] 49 CFR 171.1

few DOT classifications in the Hazardous Materials Regulations may be used to identify low-level waste. Of these, LSA and SCO are usually the most desired when transporting waste from D&D operations because of the ability to use less restrictive packagings.

To identify waste as LSA material or SCO, radiological waste characterization is necessary and it shall provide information on the radionuclide activity distribution within and/or on materials. The WCO will need training on the DOT hazard classification requirements or assistance from personnel trained on the DOT Hazardous Materials Regulations with emphasis on characterization of Class 7.

Candidate SCO wastes consist of non-radioactive material that are radioactively contaminated (i.e., radioactivity distributed on the surfaces the object; however, not distributed throughout the material). Examples of candidate SCO include process equipment, tools, furnishings, cabinets, laboratory equipment, sheet metal, piping and plumbing, plastics (i.e., sheeting, tubing), light fixtures, gloveboxes and hoods, ducting, wall board, flooring, cardboard, and building rubble.

Unlike most other DOT classifications for Class 7 radioactive materials, calculating the contribution of each radionuclide to the overall activity does not apply to SCO determinations. Rather, each individual type of emitter is compared to its contamination limit. For example, if both beta/gamma emitters and high toxicity alpha emitters[6] are present, the SCO limits for both apply independently. Knowing what radionuclides are contaminating the item is important so that the appropriate limit can be applied. After identifying the radionuclides and verifying the applicable limits are individually met, the LLW may be identified as SCO. For DOE LLW with transuranics, the high toxicity alpha composition will be the most limiting and impact the classification as SCO. As DOE radiological controls established through 10 CFR 835 are expressed in units of dpm/100cm^2, the DOT limit[6] for fixed and inaccessible high toxic alpha contamination is 480 million dpm/100cm^2 (non-fixed, accessible high toxic alpha is limited at 24,000dpm/100cm^2). For various metal debris waste, the TRU/LL discrimination of SCO waste will occur at a surface activity of 1 to 10 million dpm/100cm^2. Off-the –shelf radiation instrumentation is challenged to process count rate this high and scintillation efficiency may require modification to accurately quantify activities.

Candidate LSA wastes consist of radioactive materials that are incorporated throughout a matrix. Examples of candidate LSA wastes include solutions, sludges, filter media, radionuclides chemically

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[6] A high toxicity alpha emitter is an alpha emitter that is not specifically included in the definition of "low toxicity alpha emitter" (49 CFR 173.403; 10 CFR 71.4)

bound or absorbed into materials (i.e., swipe or rag, biological wastes, unbound paper), activated metals and materials, soil, and material specifically defined as LSA (e.g., depleted uranium, nuclides with unlimited A_2). Most options for categorizing as LSA are based on an allowed activity per gram derived from the A_2 of the waste and demand some qualitative distribution of the radionuclides throughout the material (e.g., distributed throughout or essentially uniformly distributed).

Meeting DOT Hazardous Materials Regulations may be challenging, especially when characterization shall be performed on wastes already containerized (see Appendix C). Programs such as ALARA (as low as reasonably achievable) are incorporated to provide radiological protection to the LLW worker. The technical, economic, and safety aspects, including, radiological, and chemical exposure, shall be considered when determining at which point additional measurements for detailed characterization will jeopardize ALARA or impose unacceptable costs. If additional characterization or hazard classification is too problematic for a project, using conservative packaging (e.g., Type A or Type B packaging) may be necessary. The project team may have to make a choice: incur a potential cost increase in packaging or obtain additional waste characterization data to satisfy DOT hazard classification requirements.

3.1 Characterization Process

Characterization of waste involves data analysis, of which the key component is waste knowledge. Waste knowledge used to characterize LLW eliminates unnecessary or redundant physical and chemical testing. Regulators have broadly interpreted “waste knowledge” or “acceptable knowledge” of a waste to include, where appropriate:

- Process knowledge which refers to detailed information on processes that generate wastes subject to characterization, or to detailed information (e.g., nondestructive assays, waste analysis data or studies) on wastes generated from processes similar to that which generated the waste originally characterized. LLW may be characterized by waste knowledge, sampling and laboratory analysis, or a combination of these. The use of waste knowledge alone is appropriate for wastes having physical properties that are not conducive to taking a laboratory sample or performing laboratory analysis, and hazardous situations that may jeopardize ALARA. The use of waste knowledge may be the most appropriate method for waste characterization when increased radiation and chemical exposures are a concern.
- Records of analyses
- A combination of both process knowledge and records of analyses, supplemented with chemical analysis[7]

[7] 62 FR 62079, 54 FR 48111, and OSWER 9938.4-03 (April 1994)

- Waste Isolation Pilot Plant (WIPP) Acceptable Knowledge (AK). This is a compilation of process knowledge that is formally reviewed and approved by the WIPP Program. When LLW originates from TRU waste generation activity, the WIPP radiological characterization AK is often useful for LLW disposition. Isotopes present and isotopic fractions are captured by WIPP AK.

3.2 Characterization Documents

DOE M 435.1-1 requires use of a program that provides for an auditable, retrievable storage system for waste characterization documentation. The Manual calls for maintaining documentation for waste generation, characterization, shipment, and certification. For example, the LLW shall be certified as meeting waste acceptance requirements before it is transferred to the facility receiving the waste. Documenting the waste characterization process and the information used to complete the DOT hazard classification is essential. The documentation should include data collected to support assumptions. For LSA and/or SCO determinations, the documentation shall provide information on radioactivity distribution within and/or on items. When the data collected does not support DOT hazard classification as LSA or SCO, a decision shall be made as to the feasibility of collecting additional data to support such a determination. Appendix D provides a list of the data necessary for complete DOT hazard identification as LSA or SCO.

Characterization and hazard classification documentation should clearly and completely record the methodologies used. An independent review of the documentation should result in the same outcome. Any changes to the characterization or the hazard classification process should be noted in the documentation. These requirements are similar to those of the waste transfer system required by DOE M 435.1-1 for transferring responsibility for management of LLW and for ensuring availability of relevant data, including transportation information.

3.3 Training

Persons responsible for determining if a waste meets the LSA or SCO criteria shall be knowledgeable of the DOT Hazards Materials Regulations and the specific requirements for LSA materials and SCO. Persons charged with DOT hazard classification shall recognize the data needed to make these determinations and be able to clearly document the process.

4.0 STANDARD FOR LSA/SCO DETERMINATION

4.1 Initial Considerations

LLW often may be classified as LSA material or SCO. The following key preliminary determinations shall be made before considering identification of LLW as LSA or SCO.

- Does the LLW meet the defining criteria for Class 7 radioactive material?
- Does the LLW meet the definition of an excepted material (e.g., limited quantity)?
- Does the LLW contain one or more fissile nuclides and is not fissile excepted?
- Is the LLW Special Form?
- Does the activity of the LLW as packaged fall below or exceed Type A?
- What is the physical matrix configuration of the LLW (e.g., solids, point-sources, liquids)?
- Will the external dose rate of the packaged waste exceed an external radiation level of 10 mSv/h (1 rem/h) at 3 meters from the unshielded waste?[8]

Establishing these items (as noted in Appendix D) allows determination of when to seek identification as LSA material or SCO.

4.2 "Distributed Throughout" as Applicable to LSA Material

The concept of "distributed throughout" provides for both qualitative and quantitative methods to be used to determine if the activity of the radioactive material is considered distributed throughout. NUREG-1608, the joint NRC/DOT standard, provides a means to qualitatively determine if the distribution of the radioactivity is acceptable for either "distributed throughout" or "essentially uniformly distributed throughout" the matrix.[9] Any information available to estimate whether the criteria stated in NUREG-1608 is satisfied will be acceptable. Alternative methods of determining if the radioactivity is "distributed throughout" may be acceptable, provided the determination is adequately justified.

- Qualitative techniques may be used for LSA materials having radioactivity in quantities that do not exceed A_2 and where the activity is not highly stratified. When the total activity does not exceed A_2, and the activity is known to be well distributed, it is not necessary to physically divide up the candidate LSA material into specified volume portions and compare the activities of each volume.
- A more rigorous, detailed, qualitative and quantitative analysis is more appropriate for LLW with radioactivity exceeding A_2.

Identification as LSA material and SCO is based on the radioactive component, and not the content of the package as a whole. When possible, the DOT hazard classification and determination of LSA materials or SCO should be performed before placing the waste into a container. For example, several bags of waste

[8] 49 CFR 173.427 establishes additional packaging and transportation requirements for LSA and SCO.
[9] NUREG-1608, 4.2.2 and 4.2.3

may be placed into one container. Each bag placed meets the criteria for LSA material. Some bags may contain considerably higher activities than other bags, but each bag is not required to meet the "distribution throughout" concept based on the entire content of the container once it is filled. The detailed documentation for each bag of waste provides justification for the LSA determination.

4.3 LSA/SCO

NUREG-1608 is a resource for identifying candidate LSA material and SCO. NUREG-1608 provides methods for grouping, packaging and shipping that are not specifically indicated by regulation. The following evaluation questions, in conjunction with NUREG-1608, can be used to identify candidate LSA material and SCO.

- Is the LLW a non-radioactive material that is radioactively contaminated (i.e., radioactivity on the surfaces)? If the answer is "yes," the material is SCO-candidate material.
- Is the radionuclide(s) "distributed throughout" the matrix (i.e., incorporates radioactivity throughout the material rather than being distributed on the surface) or is it an "activated" material? If the answer is "yes," the LLW is candidate LSA material.
- Determining average specific activity is essential. Activities that exceed limits for Type A packaging require both qualitative and quantitative determinations, both in the type and distribution of the activity.

4.3.1 LSA Material

LSA material has a limited specific activity which satisfies the descriptions and limits set forth in 49 CFR 173.403. LSA material shall be in one of three groups: LSA-I, LSA-II, or LSA-III. For most LSA considerations, determining the average specific activity of the radionuclides per gram of matrix (i.e., activity/gram) is important.

4.3.1.1 LSA-I

This group allows shipment of very low specific activity materials. A waste can qualify four ways as LSA-I material; three are specifically defined and the fourth is based on activity distribution. They are as follows:

1. uranium or thorium ores, or concentrates of these ores, intended to be processed for their nuclide contributions.
2. solid unirradiated natural uranium, or depleted uranium or natural thorium (including their solid or liquid compounds/mixtures).
3. any radionuclide, excluding fissile material, with an "unlimited" A2 value.

4. The fourth option is based on activity distribution and concentration. LSA-I includes other radioactive material, excluding fissile material in quantities not excepted under §173.453, in which the activity is distributed throughout and the estimated average specific activity does not exceed 30 times the values for activity concentration specified in §173.436, or 30 times the default values listed in Table 8 of §173.433.

The level of radioactivity and its "distribution throughout" the matrix shall be considered. Most LSA-I candidate materials are not expected to exceed A_2; therefore, qualitative techniques may be used for activity distribution determinations. The activity limit for LSA-I is based on the exempt material concentration values in §173.436. These are very conservative values. For example, contaminated soils containing natural uranium and thorium are limited to 30 Bq/g (810 pCi/g). LSA-I material is primarily intended for wastes resulting from decommissioning and environmental restoration activities. Earth, concrete, and rubble may be considered LSA-I as long as they comply with the regulatory limitations.

4.3.1.2 LSA-II

This group includes nuclear reactor process wastes, such as lower-activity resins and filter sludge. It can also include activated equipment. The activity does not have to be uniformly distributed, but it does need to be distributed throughout. The following two options are used to qualify materials as LSA-II.

1. Water with tritium concentration up to 0.8 TBq/L
2. Other radioactive material in which the activity is "distributed throughout" and the average specific activity does not exceed 10-4A2/g for solids and gases, and 10-5 A2/g for liquids.

When grouping as LSA-II, an A2 activity determination should be made first. This will establish if a detailed, quantitative approach is necessary for qualifying the activity distribution.

4.3.1.3 LSA-III

This group is for higher-activity materials such as solids (e.g., consolidated wastes, activated materials), excluding powders, which meet the requirements of §173.468 and in which:

- the radioactive material is distributed throughout a solid or a collection of solid objects, or is essentially uniformly distributed in a solid compact binding agent (concrete, bitumen, ceramic, etc.);
- the radioactive material is relatively insoluble, or it is intrinsically contained in a relatively insoluble material, so that, even under loss of packaging, the loss of Class 7 (radioactive) material per package by leaching when placed in water for seven days would not exceed 0.1 A2; and

- the estimated average specific activity of the solid, excluding any shielding material, does not exceed 2 × 10-3 A2/g.

LSA-III solids can be activated metals or processed waste. LSA-III material shall be physically tested to provide evidence of insolubility. The activity limits shall be qualitatively and quantitatively determined. The activity distribution may be “distributed throughout” or “essentially uniformly distributed” depending on the physical characteristics. LSA-III materials are usually planned and documented thoroughly to provide empirical evidence of qualification. As for LSA-I and LSA-II, it is essential to determine the A2 fraction for LSA-III.

4.3.1.4 Description

LLW meeting LSA-I, LSA-II, or LSA-III criteria shall be described using the “Radioactive Material, Low Specific Activity…” shipping name with the appropriate LSA group as presented in the §172.101 Hazardous Materials Table. Reference for determining appropriate packaging options for LSA materials is provided in §173.427(b) and (c).

When the LLW does not meet the criteria of LSA material, or the matrix will not allow for reasonable determination of being “distributed throughout” for LSA-I or LSA-II, “essentially uniformly distributed” for LSA-III, or the waste exceeds the LSA limit (based on reasonable estimate), the LLW shall be packaged in either Type A packaging or approved Type B packaging depending on the A2. The shipping name for both options is listed in the Hazardous Materials Table.

4.3.2 Surface Contaminated Objects

An SCO is a solid object that is not itself radioactive but has radioactive material distributed on its surface. SCO are divided into two groups: SCO-I and SCO-II.

4.3.2.1 SCO-I

An SCO-I is a solid object that meets all of the following criteria.

1. The non-fixed contamination on the accessible surface averaged over 300 cm2 (or the area of the surface if less than 300 cm2) does not exceed 4 Bq/cm2 (10-4 microcurie/ cm2) for beta and gamma and low toxicity alpha emitters, or 0.4 Bq/ cm^2 (10-5 microcurie/ cm^2) for all other alpha emitters.
2. The fixed contamination on the accessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 4 × 104 Bq/ cm^2 (1.0 microcurie/ cm^2) for beta and gamma and low toxicity alpha emitters, or 4 × 103 Bq/ cm^2 (0.1 microcurie/ cm^2) for all other

alpha emitters.

3. The non-fixed contamination plus the fixed contamination on the inaccessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 4 × 104 Bq/ cm^2 (1 microcurie/ cm^2) for beta and gamma and low toxicity alpha emitters, or 4 × 103 Bq/ cm^2 (0.1 microcurie/ cm^2) for all other alpha emitters.

4.3.2.2 SCO-II

An SCO-II is a solid object that exceeds the limits for SCO-I and that meets all of the following criteria.

1. The non-fixed contamination on the accessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 400 Bq/ cm^2 (10-2 microcurie/ cm^2) for beta and gamma and low toxicity alpha emitters, or 40 Bq/ cm^2(10-3 microcurie/ cm^2) for all other alpha emitters.
2. The fixed contamination on the accessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 8 × 105 Bq/ cm^2 (20 microcurie/ cm^2) for beta and gamma and low toxicity alpha emitters, or 8 × 104 Bq/ cm^2 (2 microcuries/ cm^2) for all other alpha emitters.
3. The non-fixed contamination plus the fixed contamination on the inaccessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 8 × 105 Bq/ cm^2 (20 microcuries/ cm^2) for beta and gamma and low toxicity alpha emitters, or 8 × 104 Bq/ cm^2 (2 microcuries/ cm^2) for all other alpha emitters.

SCO-I has the more restrictive contamination limit. Unlike most other DOT classifications for Class 7 radioactive materials, calculating the contribution of each radionuclide’s activity to the overall activity does not apply to SCO determinations. Rather, each individual type of emitter is compared to its contamination limit. For example, if both beta/gamma emitters and high toxicity alpha emitters are present, the SCO limits for both apply independently. Knowing what radionuclides are contaminating the item is important so that the appropriate limit can be applied. After identifying the radionuclides and verifying the applicable limits are individually met, the LLW may be identified as SCO.

4.3.2.3 SCO Characteristics

An SCO is a solid object that is not itself radioactive but has radioactive material distributed on its surface. This differs significantly from LSA material where the radioactivity is incorporated into the LLW. At DOE sites, contaminated process equipment, scrap metal, and some personnel protective equipment are common types of SCO.

When asked, “Is there an object size below which a collection of small, contaminated objects may be categorized and shipped as LSA material as opposed to SCO?” The DOT and NRC responded:

> “No…Nonradioactive objects whose surfaces are contaminated with radioactivity are clearly candidate SCO, not LSA material, regardless of size.”[10]

This response shall be qualified. When asked the question, “What general categories of materials are intended to be shipped as LSA?”, DOT and NRC responded by stating that

> “[o]ther examples of LSA-II would be demolition rubble which exceeds LSA-I limits…”[11]

A disparity appears to exist between these answers. How can any non-radioactive object, regardless of size be candidate SCO only and yet demolition rubble be LSA-II candidate? The key is in understanding “small object” and “discrete item.” For the purposes of SCO and LSA classification, a “small object” and a “discrete item” are not the same. The NRC defines a discrete item in the NRC Branch Technical Position as:

> (a) the volume of a piece or section that is <0.00028 m3, and
>
> (b) having a specific nuclide activity in the piece or section above a specified value (activity level differs depending on primary gamma emitters and NRC waste Class A, B or C).

For purposes of SCO and LSA classification, this paragraph defines “small objects” as being <0.00028 m3; objects exceeding this size are identified as “discrete” for classification purposes. The term and how it’s defined here is not consistent with that presented by the NRC for waste volumetric or weighted averaging (the DOT activity limits are based on a credible transport accident scenario, not a LLW disposal site intruder scenario). The DOT considers small objects to be more likely uniform in their level of contamination. Larger objects have a greater chance of hot spots or nuclide accumulations. Therefore, these larger objects are considered by DOT to be discrete and require greater discernment in classifying as SCO.

In section 4.2.4 of NUREG-1608 states “…materials which the [NRC Branch Technical Position]

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[10] NUREG-1608, 4.1.4
[11] NUREG-1608, 4.1.1

recommends should be considered discrete items for LLW classification should also be considered discrete items and be evaluated individually against the LSA definitions, as appropriate." For the purposes of LSA and SCO classification, a discrete item is:

- as presented in the NRC Branch Technical Position, an activated material or metal, a component incorporating radioactivity in its design, or a contaminated material, if: (1) the volume of the item is <280 cm3 (0.00028 m3); and (2) for primary gamma emitting nuclides (Co-60, Nb-94, Cs-137/Ba-137m) exceed the limits expressed in Table A, or for other nuclides, exceed the limits expressed in Table B.
- as presented in NUREG-1608, an object that exceeds 280 cm3 (0.00028 m3); any item smaller than this is considered a "small object".

For LSA and SCO classification, any object that exceeds 280 cm3 is considered discrete and shall be evaluated independently. Items smaller than 280 cm3 are considered "small" objects, and are considered more likely uniform in their level of contamination. However, if the "small" object is considered to be a discrete item by the NRC BTP, the item shall be evaluated independently against the LSA/SCO criteria.

The DOT has stated that concentration averaging for some materials to make an LSA determination is not acceptable[12] as they are more appropriately candidate SCO (e.g., non- radioactive contaminated objects generated from D&D operations).

4.3.2.4 SCO Activity Limits

Once an object is determined to be candidate SCO, the activity on the object shall be assessed against the SCO limits. Contamination limits, separated by beta/gamma/low toxicity alpha and other alpha, are identified for three situations:

1. Non-fixed (smearable) contamination on accessible surfaces
2. Fixed (non-smearable) contamination on accessible surfaces
3. All contamination (non-fixed and fixed) on inaccessible surfaces

The level of assessment needed to identify an object as SCO depends primarily on the activity contribution of low level waste that will be placed into a packaging. If the total activity of the package exceeds the A_2, a more detailed, quantitative assessment of the three contamination levels listed above shall be conducted. Depending on the object itself, this may be exceedingly problematic. In some cases, obtaining such level of detail is beyond cost benefits and/or ALARA principles. The better option may be

[12] NUREG-1608, Section 4.2.4

to manage the waste to allow multiple Type A packages or ship utilizing a Type B packaging or DOT Special Permit.

SCO candidate items for which the total activity does not exceed the A_2 value are more easily categorized. Physically obtaining the non-fixed contamination levels is imperative except when the total activity is less than the SCO limit for non-fixed contamination on accessible surfaces. Individuals making determinations shall provide evidence to support the categorization.
Methods employed to determine contamination levels include one or more of the following:[13]

- Wiping and analyzing for activity (non-fixed)
- Surface sampling and sample analysis (fixed plus non-fixed) Radiation level measurements (fixed plus non-fixed)
- Process knowledge
- Analyses
- Reference to previously satisfactory determinations of a sufficiently similar nature

Several factors shall be considered when applying these methods in distinguishing non-fixed, accessible contamination from fixed contamination on inaccessible surfaces. The following shall be determined and documented, when applicable:

- The total activity concentration in and on the object
- The radionuclide mix of contamination on the different surfaces
- The relative uniformity of distribution of the contamination on the surfaces
- The physical makeup of the object and the role the object’s structure plays in mitigating radiation emanating from inaccessible surfaces
- The proximity of the contamination levels to the SCO limits

For those objects for which the total activity of the package will not exceed the A_2 value, the thoroughness of methods used is dependent on the low-level waste. For example, performing detailed assessment on every item is not necessary. One may assume that the surface of smaller objects (e.g., <280 cm^3)[14] have uniform contamination over their surfaces. General, random analysis of some of the objects, along with dose rate measurements, may be sufficient to determine SCO applicability.

[13] NUREG-1608, 3.4.1
[14] NUREG-1608, 4.1.4

4.3.2.5 Alternate SCO-II Determination

Another approach is provided in NUREG-1608[15] that allows for identifying SCO-II without detailed, quantitative measurements of fixed and inaccessible contaminations. Under this allowance, SCO-II is met as long as all of the following are implemented. (NOTE: Waste containing transuranics will most likely exceed the requirements of item #5 and another methodology would be used for making an SCO-II determination because additional data or technical basis documentation will be needed to ensure SCO-II limits are not exceeded).

1. The package is an authorized package under §173.427.
2. The consignment is shipped exclusive use.
3. The non-fixed contamination on the accessible surfaces of all objects do not exceed SCO-II limits.
4. The total activity on the object(s) (fixed plus non-fixed), divided by the mass of the object(s), does not exceed 10-4A2/gram. (This is not an LSA determination, but rather, it is to ensure there are no obvious "point-source" locations that could cause concern if in an accident.)
5. The alpha-emitter (or "other alpha") contribution in the package does not exceed 0.025 A2 (i.e., 2.5% of the package's derived A2).

A majority of candidate SCO may be identified using this short-step approach. The key is to remember that, in most cases, the level of contamination does not need to be precisely determined as long as sufficient information supports a reasonable determination that the contamination levels do not exceed the applicable SCO limit. Those identifying SCO should recognize that SCO contamination limits are based on the activity averaged in a given 300 cm^2 area. Because most contamination surveys performed by qualified professionals cover a 100 cm^2 area, the contamination survey should average the amount of radioactivity measured from multiple wipe samples of varying 100 cm2 areas within any given 300 cm2 area.16[16]" When basing an SCO determination on the activity within a given 300 cm2 area, geometric calculations are also necessary to provide "reasonableness" in the assessment.

[15] NUREG-1608, 3.3.1

[16] NUREG 1608, Section 3.4.4

4.3.2.6 Description and Packaging

LLW that meets either SCO-I or SCO-II criteria may be identified and described using the "Radioactive Material, Surface Contaminated Object…" shipping name and the appropriate SCO group identified, as presented in the §172.101 Hazardous Materials Table. Reference for determining appropriate packaging options for SCO is provided in §173.427(b) and (c).

If the object is such that its configuration will not allow for reasonable determination of contamination levels, or it is determined to exceed the SCO-II limit, or it cannot meet the definition of SCO, LLW shall be packaged in either Type A packaging or approved Type B packaging depending on the A_2 fraction.

4.3.3 Mixed (LSA and SCO) Content Package

A packaging may contain both LSA material and SCO. The Hazardous Materials Regulations address the possibility of having two hazardous materials with differing proper shipping names in a single packaging. DOT and NRC recognized how frequently this occurs and provided the means by which mixed LSA material and SCO content can continue to be shipped in one packaging[17]. In the case of a packaging with both LSA and SCO, DOT recognized that the hazard communication and emergency response information is the same for LSA and SCO; therefore, in NUREG 1608, DOT/NRC stated that showing a single proper shipping name, specifically LSA, would be adequate for packagings containing less than an A_2[18].

When placing LSA material and SCO into one packaging, both the object(s) and the LSA material(s) shall meet their respective definitions, including activity limits, before being placed into the same waste container. Any acceptable determination methodology, or combination of methodologies, may be employed to document and reach these determinations.

The DOT/NRC standard underlines the need to ensure the higher dose material meets the LSA- II material definition with an average specific activity of less than 10-4 A_2 /g, but also the external radiation level from the unshielded material shall not exceed 10 mSv/h (1 rem/h) at 3 meters from the unshielded material (see § 173.427(a)(1)). Compliance with this requirement does not allow a person to take credit for shielding material surrounding the LSA material. Thus, without any shielding, the dose rate would not exceed the limit.

[17] NUREG-1608, Section 6.1

[18] 49 CFR 172.202(a)(2), NUREG 1608, 172.203 (d)(1), 173.433(g), 173.24a(c)

4.3.3.1 Total Activity of the Package Exceeds A_2

The A_2 fraction of the package content is very important when mixing LSA material and SCO. If the total activity exceeds A_2, detailed methodologies shall be used to document the content. This applies even when, individually, the SCO and LSA materials do not exceed A_2 When the total activity of the package exceeds A_2, the identity and description of the content shall be based on the waste with the greatest contribution to the A_2 fraction. Therefore, if the SCO contributes >50% of the A2 fraction, the entire package contents will be described using the shipping description for "Radioactive Material, Surface Contaminated Object…" with the identity of the applicable SCO group. When the LSA material contributes the greater fraction, the package contents will be described as "Radioactive Material, Low Specific Activity…" with the addition of the appropriate LSA material group.

4.3.3.2 Total Activity of the Package Does Not Exceed A_2

The identity and description for mixes of LSA material and SCO that do not exceed A2 activity in the package is much simpler. In these cases, the package is described for shipping based on the LSA material content, "Radioactive Material, Low Specific Activity…" with the addition of the appropriate LSA material group.

LSA material determination, based on activity per gram, cannot include the mass of the SCO- candidate items. Consequently, when determining if the material meets the defining criteria for Class 7 radioactive material, the SCO shall be assessed without regard to the LSA material. Once again, the overall activity of the package (e.g., not exceeding A2) and the nearness of the material/objects to their respective limits will decide the methodology employed to make this determination.

For example, the material to be transported from a decommissioning project may include radioactively-contaminated metals and wood from above-ground structures along with soils (i.e., LSA candidate material). Based on in-field visual observations during packaging loading, approximately 25% of the volume of the packaging is consumed by soils. The mass of the soil is then determined based on the mass/volume of the soil and the amount of soil estimated in the packaging. The net mass of the SCO can be determined by subtracting the soil and packaging tare weight from the total gross weight of the package. These steps result in a documented methodology that can be used to support a determination of the package content as LSA material/SCO. Any reasonable person using the same data should be able to arrive at the same conclusion. This section mentions methodologies presented in NUREG 1608 sections 4.1.1 and 6.1.1, the shipper is responsible for selecting and documenting methodology used to satisfy applicable regulatory requirements.

4.3.4 Additional Considerations

Identification of LSA material and SCO is neither a quick, or easy process. The regulations present complexities when applied to actual situations. The NUREG-1608 standard document bridges many of the gaps between operations and regulations. Although this document attempts to provide further assistance, other issues may arise when determining whether low-level waste meets the requirements to be identified as LSA material or SCO.

4.3.4.1 Equipment and hardware that may contain liquids

After being used in a process involving radioactive materials, these objects may be determined to be SCO that contain LSA liquids. Remember, SCO are always "solids." Such equipment and hardware may include:

- pumps valves
- electrical capacitors and transformers
- lab wastes
- empty packagings tanks
- piping (especially with multiple and irregular bends)

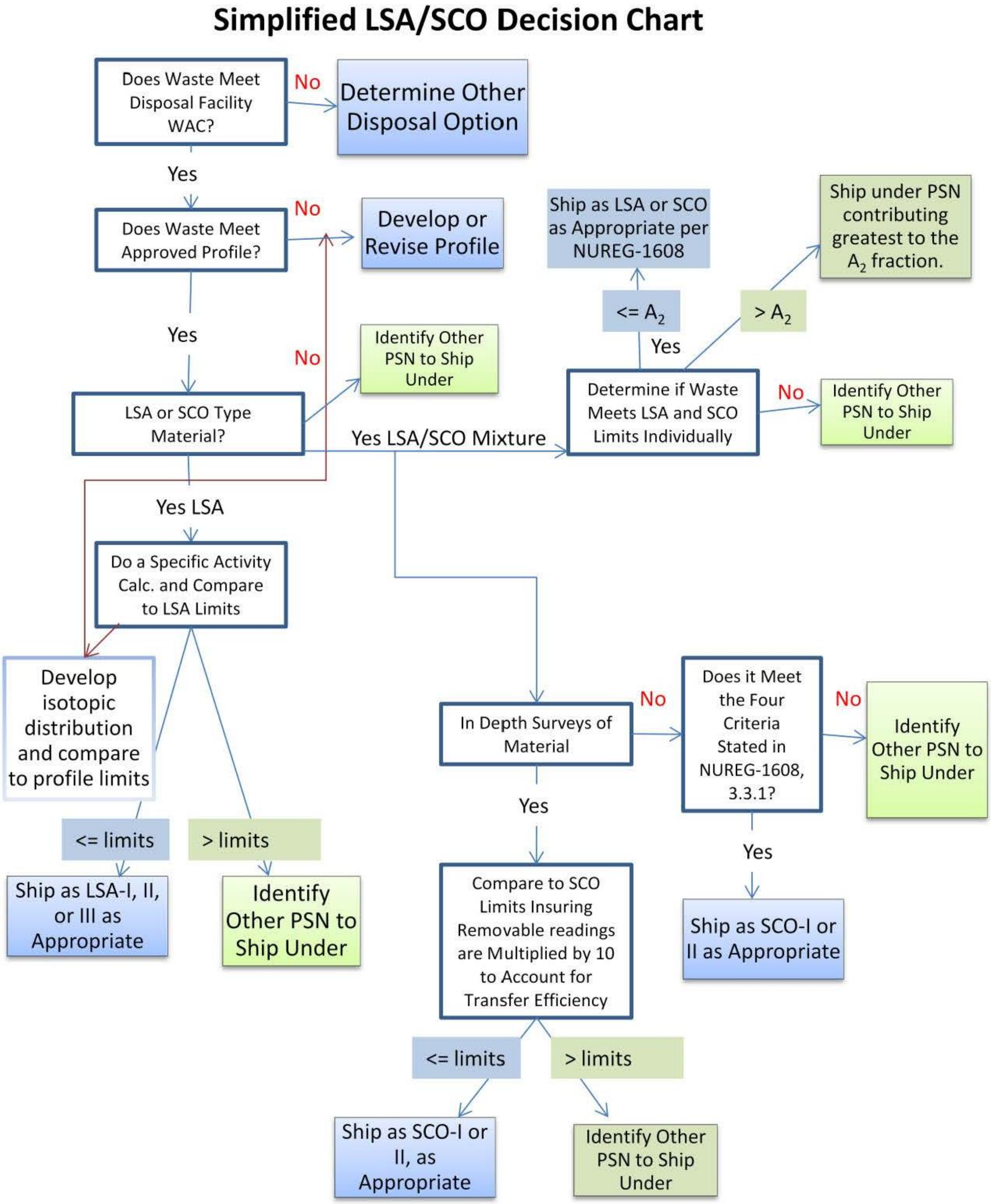
4.3.4.2 High activity materials hidden or shielded by other matrices (intentionally or unintentionally)

Remember, LSA material determinations are based on each "material" and not necessarily the entire matrix of a given package. In clean-up activities, high-activity LSA material might be placed inside other, lower-activity LSA material so as to provide shielding for package and transport limits. The issue with these situations is not with the initial categorization, but with maintaining the desired configuration during transport and unloading. When the overall matrix is being used to shield a high-activity matrix, the load configuration of the package shall not be changed during transport or during all unloading operations.

4.3.4.3 High alpha content based on "overall" waste characterization

A general waste characterization decision may be made based on the overall composition of wastes from a given facility. Recognizing the various wastes generated from differing processes within a given facility is important. For example, one process run may yield high alpha contaminates in the waste stream. This waste is consolidated with other wastes that do not share this high-alpha composition, but the volume of waste to be generated shall be considered. Analyzing waste may be cost effective in terms of LSA material/SCO categorization. This will be very important if relying on the SCO-II short-step approach which limits "other alpha" contribution to 0.025 of the A2.

APPENDIX A


Simplified LSA/SCO Decision Chart
Does Waste Meet Disposal Facility WAC?
No
Determine Other Disposal Option
Yes
Does Waste Meet Approved Profile?
No
Develop or Revise Profile
Yes
LSA or SCO Type Material?
No
Identify Other PSN to Ship Under
Yes LSA/SCO Mixture
Determine if Waste Meets LSA and SCO Limits Individually
No
Identify Other PSN to Ship Under
Yes
<= A2
Ship as LSA or SCO as Appropriate per NUREG-1608
> A2
Ship under PSN contributing greatest to the A2 fraction.
Yes LSA
Do a Specific Activity Calc. and Compare to LSA Limits
Develop isotopic distribution and compare to profile limits
<= limits
Ship as LSA-I, II, or III as Appropriate
> limits
Identify Other PSN to Ship Under
In Depth Surveys of Material
No
Does it Meet the Four Criteria Stated in NUREG-1608, 3.3.1?
No
Identify Other PSN to Ship Under
Yes
Ship as SCO-I or II as Appropriate
Yes
Compare to SCO Limits Insuring Removable readings are Multiplied by 10 to Account for Transfer Efficiency
<= limits
Ship as SCO-I or II, as Appropriate
> limits
Identify Other PSN to Ship Under

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APPENDIX B. DIFFERENCES BETWEEN NRC AND DOT

The DOE LLW program, excepted from 10 CFR 61, takes a different approach to facility requirements and waste classification. For many years, the DOE has disposed of its LLW onsite, where available, in lands with past, present and future access restrictions. The DOE generated- LLW does not share the generic nature of LLW generated in commercial facilities. Except for some DOE sites, LLW is seldom generated at the same location in which it is disposed. Thus, the DOT regulations impacting packaging and transportation of hazardous materials in commerce, including radioactive material, shall be considered.

NRC Regulations. The NRC regulations, 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste"[19] establish the LLW classification system which is based on the volume of the waste (Ci/m3) or weight of the waste (nCi/g), as applicable. The NRC regulations establish three LLW Classes: Class A, Class B and Class C. LLW deemed to exceed Class C (termed "greater than Class C" or GTCC) are not acceptable for near surface land disposal. The LLW Classes and their associated activity limits, and other facility controls, are established to limit potential exposure at 500 mrem/year whole body to an inadvertent intruder who resides on a closed disposal site (closed for 100 or more years) and is unaware of the disposed radioactive waste.

DOT Regulations. DOT regulates the transportation of LLW that meets the defining criteria of Class 7 (radioactive) material. The Class 7 material transport regulations are derived from a very different model than the one used by the NRC for a near surface disposal facility since transportation is a short-term event. The DOT has historically adopted, with some amendments and domestic exceptions, the International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Material[20]. In establishing the activity limits for Class 7 material, the IAEA modeled a credible transport accident scenario in which a person is exposed to a radioactive material that has been released from the package (i.e., a Type A package[21]). The person is deemed to be at a distance of one meter from the radioactive content for a 30 minute period. The activity of the radioactive material is limited so that the total dose to the nearest person does not exceed five Rem whole body. Exposure pathways include external photon and beta emission dose, internal dose via inhalation, skin contamination and ingestion doses, and submersion

[19] United States Code of Federal Regulations, Title 10, Part 61

[20] Regulations for the Safe Transport of Radioactive Material, Safety Requirements No. TS-R-1, Vienna, Austria, May 2009, STI/PUB/1384, IAEA (2009)

[21] A Type A package is required to withstand, without loss or dispersal of content or significant increase in dose rate, normal conditions of transport. In a transportation accident, the Type A package may be damaged to the degree the radioactive content escapes the containment system. Loss of containment and shielding is accounted for in the IAEA TS-R-1 dosimetric model used to establish Type A activity limits.

dose due to gaseous isotopes[22]. This dosimetric model is called the "Q System."

Separate criteria are applied to two materials types: (1) uniform distribution throughout of the radionuclides; and (2) non-radioactive materials that are radioactively contaminated. Both material types shall exceed specified limits and shall also exceed a total consignment value to be regulated as radioactive material in transport (see Table 1).

Table 1. Application of the Definition of Class 7 Material for Transport

<table>
<tr><th>Material Type</th><th colspan="3">Shall exceed both columns to be regulated in transport as Class 7 (radioactive) material</th></tr>
<tr><td>Activity Concentration (Homogeneous Matrix)</td><td>Nuclide Specific Values (Bq/g)</td><td rowspan="3">and</td><td rowspan="3">Nuclide Specific Consignment Values (Bq total)</td></tr>
<tr><td colspan="2">Or</td></tr>
<tr><td>Contamination Level (Non-radioactive material)</td><td>Activity Limits specified in Definition of Contamination (Bq/cm2)</td></tr>
</table>

CLASSIFICATION CRITERIA

The specialty of the DOE LLW coupled with onsite disposal affords DOE a more site-specific classification system taking into account both known environmental and waste characteristics. Similar to the NRC intruder-based scenario, the DOE LLW disposal requirements share similar criteria albeit more dose restrictive (DOE requirements in DOE Manual 435.1-1 [23]establish a 100 mrem/year limit for chronic exposures and 500 mrem limit for acute exposures).

In July 1998, the NRC Spent Fuel Project Office, in conjunction with the DOT Research and Special Programs Administration, published NUREG-1608, "Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects"[24]. The primary purpose of NUREG-1608 is to assist shippers in classifying and preparing LSA and SCO for transport. The document provides an acceptable means to allow the commingling of LSA material and SCO into a single package for transport.

[22] Other assumptions and special considerations were applied for alpha emitting special form, neutron emitters, Bremsstrahlung radiation, tritium and its compounds, radon and its progeny, and low specific activity material having unlimited Type A values.
[23] United States Federal Register, December 27, 1982, page 57446 (47 FR 57446)
[24] Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects, NUREG-1608 (NRC) and RAMREG-003 (DOT), July 1998

In NUREG-1608, section 4.2.4, the NRC and DOT answers if compliance with the NRC BTP can demonstrate that a mixture of candidate LSA material are distributed throughout or essentially uniformly distributed, as applicable.

> "Mixtures of LLW types or streams which meet the January 17, 1995, "Branch Technical Position of Concentration Averaging and Encapsulation," (NRC, 1995a) can be assumed to be either distributed throughout or essentially uniformly distributed, as applicable. This determination can be used in place of the determination described in Section 4.2.3 [IAEA's method], irrespective of the size of the container in which it is packaged for transport. Further, if averaging over the volume or mass of the waste is permitted by the concentration averaging Technical Position (TP) of disposal classification purposes, similar averaging over the mass of the waste is generally acceptable for LSA specific activity determination."

The first few sentences of this section imply that any waste characterized in accordance with the 10 CFR 61.55[25] and the BTP on Concentration Averaging and Encapsulation should be acceptable for LSA specific activity determinations as well. However, this is not the case. The remainder of NUREG-1604, 4.2.4 qualifies the initial statement.

> "However, materials which the TP recommends should be considered as discrete items for LLW classification should also be considered discrete items and be evaluated individually against the LSA definitions, as appropriate. Further it is assumed that nuclides important to transportation are distributed in the waste to the same degree as those important to waste classification. If it believed that this assumption does not hold, a more detailed analysis would be expected by the DOT and NRC.
>
> Note that the TP contains standard for classification and averaging of some materials (i.e., contaminated materials, encapsulated materials, and sealed sources), that should not be applied for LSA material determinations. Specifically:
>
> - Nonradioactive, contaminated objects shall be classed as SCO (see section 3).
> - Encapsulated wastes should not be averaged over the weight of the solidified mass for determination of the material's weighted specific activity (as is allowed for LLW classification).

[25] Waste Classification (NRC classification of LLW for near surface disposal)

Sealed sources cannot be considered LSA material unless the source itself meets the LSA definition (specific activity limit and distribution); although the TP allows averaging the sealed source activity over the entire waste form for LLW classification, this practice is not acceptable for LSA material determinations for transport."

In May 1983, the NRC developed a Branch Technical Position (BTP) [26] on LLW classification. This BTP was expanded further in the 1995 BTP on Concentration Averaging and Encapsulation. The BTP describes overall practices acceptable to the NRC which may be used to determine the appropriate LLW Class. The BTP provides standard on how to determine the volumetric and mass concentrations of radioactivity in the LLW specifically for: (1) homogeneous wastes; (2) mixing of homogeneous wastes; (3) solidified and absorbed liquids; (4) mixing of activated materials or metals, or components incorporating radioactivity in their design; (5) contaminated materials; (6) mixing of cartridge filters; (7) waste in high-integrity containers (HIC); (8) encapsulation of solid material; (9) mixing of dissimilar waste streams (different waste types); and (10) alternative provisions.

Many of the LLW types allowed by the NRC for volumetric- or weighted- averaging are not acceptable as LSA material. Wastes that contain candidate SCO shall be assessed against the SCO criteria or be classified as Type A or >Type A for packaging and transport. The following discusses some of the differences between NRC waste characterization and DOT classification of LSA and SCO.

Homogeneous. The IAEA and DOT recognize that most LSA materials will not be homogeneous[27]. However, some degree of homogeneity is an important factor in considering the probability of release and the consequences of potential dispersion in a transportation accident. Therefore, the IAEA and DOT have provided standard that can be used to determine if a given material is homogeneous enough to be considered "distributed throughout" and available for LSA determination[28].

The NRC's application of homogeneous as applied to waste is considerably different.

> "A homogenous waste type is one in which the radionuclide concentrations are likely to approach uniformity in the context of the intruder scenario used to establish the values included in Tables 1 and 2 of 10 CFR 61.55 (i.e., intruder interactions with the waste are assumed to take place 100

[26] Branch Technical Position on Concentration Averaging and Encapsulation, NRC, 1995b, Nuclear Regulatory Commission, January 17, 1995
[27] IAEA TS-G-1.1. Section 226.4; NUREG-1608, 4.2.2
[28] IAEA TS-G-1.1, Sections 226.14 – 226.17; NUREG-1608, Section 4.2.3

years or more after disposal site closure)."

The NRC views homogeneous to be a condition that will be "arrived at" over a 100 year burial period. The IAEA and DOT view homogeneous as "real time" distribution reflected by the content of the package that is to be transported.

Volumetric Averaging. Most nuclides under 10 CFR 61.55 are limited based on an activity allowed in a given volume of waste (i.e., Ci/m3). This information may be used for DOT classification to support a "distributed throughout" determination, and if enough information available given a specific matrix, provide an activity/mass determination. In general, volumetric averaging does not correspond to activity limits placed on materials under the DOT HMR.

Weighted-Averaging. Weighted-averaging is acceptable by the NRC for waste where the activity is weight limited based on the weight of the matrix (i.e., nCi/g). As often allowed, given nuclide specific constraints, the entire weight of the matrix is considered in the NRC weighted- average nuclide concentration determination. For example, a component that has radioactive material incorporated into its design can take advantage of the entire weight of the "component" when determining activity/gram. The determination for LSA material (and likewise, the Class 7 defining criteria activity concentration for exempt material) is not allowed to take advantage of any non-radioactive portion of the matrix. Only the weight of those materials that are activated or that incorporate the radioactive material can be used to determine the activity per unit mass. The IAEA clarifies that this determination is applied to compacted material.

Compaction of material should not change the classification of the material. To ensure this, the mass of any container compacted with the material should not be taken into account in determining the average specific activity of the compacted material."[29]

Solidified and Absorbed Liquids. The NRC limits volumetric- or weighted-average nuclide concentrations of absorbed liquids to the absorbed nuclide activity divided by the volume or mass of the liquid before absorption because absorption does not appreciably bind nuclides. DOT, however, does not consider long term disposal in their activity limits and classification structure. As long as the liquid is complete absorbed (i.e., no free liquid ever present in the packaging) and will remain so the entire time from initial packaging to its final consigned destination, the LSA activity/gram can be based from the

[29] IAEA TS-G-1.1, Section 226.20

nuclide activity divided by the total absorbed mass.

Activated Materials or Metals. The NRC allows volumetric- or weighted-average nuclide concentrations for these wastes. The displaced volume or total weight of the activated material or metal is used in averaging. LSA classification of activated materials or metals is based on the weighed-average nuclide concentration. For mixtures of activated materials or metals, it is acceptable to classify each piece, or classify the group based on the highest concentration of any one piece within the group. The NRC allows, with constraints, the averaging of the concentration of nuclides over the contents of the disposal container. This method is not acceptable for LSA determination as it may allow one activated piece that exceeds LSA activity limits to be “averaged” with pieces of very low activity.

Components Incorporating Radioactivity in Their Design. The NRC activity concentration averaging for these items is relatively the same as that for activated materials or metals. Volumetric averaging cannot include void space other than those within the envelope of the component itself. The NRC, however, will allow (with constraints) the entire content of the packaging to be used to determine the nuclide weighted-average. These averaging applications are completely foreign to LSA classification, and as such, are not permitted. For classification as LSA, the radioactive part of the component shall: (1) be an activated material or metal, and (2) be a material that itself meets the definition of LSA-I, or meets the weighted concentration authorized for the specific LSA group.

Contaminated Materials. The NRC allows either displaced volumetric- or weighted-averaging to be used to determine the class of waste for contaminated materials. The NRC permits (with constraints) averaging the concentration of the radionuclides over the contents in the disposal container, either volume or weight. This includes those items that may not even be radioactively contaminated as long as they are considered part of the “component”. These methods to determine LLW activity concentrations are not appropriate for LSA or SCO classifications under the DOT HMR. Contaminated materials are not candidate LSA material and shall be considered for classification as SCO. Nuclide averaging over the entire surface area of the object(s) is not within the 300 cm^2 surface area averaging permitted by the DOT (unless the surface area of the object is <300 cm^2). Lastly, weighted-averaging for a contaminated item is only allowed by the alternate SCO-II determination method, Condition (3), as allowed in NUREG-1608, Section 3.3.1.

Cartridge Filters. The NRC allows volumetric- or weighted-average nuclide concentrations for cartridge filters and mixes of cartridge filters. The volume to use is the displaced volume of the filter (interstitial space within the filter may be included). For DOT classification purposes, most cartridge filters will have incorporated the radioactive material into or on the filter media (design dependent). Small cartridge filters (e.g., <280 cm^3) collected in waste drums may be considered dry active wastes and are LSA like for classification purposes[30]. Larger filters are considered „discrete items" by DOT, and as such, require independent classification[31]; averaging a group of filters is not acceptable unless the nuclide concentration is relatively uniform throughout the filter media. The classification of cartridge filters shall be looked at case-by-case taking into account the type of filter, its design and material of construction, the process that generated the filter, and its size/volume.

Encapsulated Material. The NRC allows nuclide concentrations to be based on the overall volume (with constraints) of the solidified mass for encapsulated routine wastes such as filters, filter cartridges, and sealed sources. This is not authorized under the DOT classification of LSA or SCO[32]. As stated in the IAEA TS-G-1.1, Section 226.11:

> "A solid compact binding agent, such as concrete, bitumen, etc., which is mixed with the LSA material, is not considered to be an external shielding material. In this case, the binding agent may decrease the surface radiation level and may be taken into account in determining the average specific activity. However, if radioactive material is surrounded by external shielding material, which itself is not radioactive … this external shielding material is not to be taken into account in determining the specific activity of the LSA material."

Discrete Items. For the purposes of LSA and SCO classification, a discrete item is:

- as presented in the BTP, an activated material or metal, a component incorporating radioactivity in its design, or a contaminated material, if: (1) the volume of the item is <280 cm3 (0.00028 m^3); and (2) for primary gamma emitting nuclides (Co-60, Nb-94, Cs-137/Ba-137m) exceed the limits expressed in Table A of the BTP, or for other nuclides, exceed the limits expressed in Table B of the BTP.
- as presented in NUREG-1608, an object that exceeds 280 cm^3 (0.00028 m^3); any item smaller than this is considered a "small object" and "…materials which the [NRC Branch Technical Position] recommends should be considered discrete items for LLW classification should also be

[30] NUREG-1608, Section 4.1.1
[31] NUREG-1608, Section 4.1.4
[32] NUREG-1608, Sections 5.1.3 and 6.23

considered discrete items and be evaluated individually against the LSA definitions, as appropriate (NUREG-1608, Section 4.2.4)."

For LSA and SCO classification, any object that exceeds 280 cm3 is considered „discrete" and shall be evaluated independently. Items that do not exceed 280 cm3 are considered „small objects". However, if the „small object" is considered to be a „discrete" item by the NRC waste classification BTP, the item shall be evaluated independently against the LSA/SCO criteria. The DOT regulations do not permit averaging of some materials for LSA determinations:

> "Note that the [BTP] contains standard for classification and averaging of some materials (i.e., contaminated materials, encapsulated materials, and sealed sources), that should not be applied for LSA material determinations."[33]

Mixing of Different Waste Types (Commingling). This matrix consists of two or more of the already discussed material/waste types, e.g., SCO (contaminated non-radioactive object) placed in a package or container commingled with LSA (radioactivity incorporated in or throughout the material). In these cases, the NRC waste classification involving averaging the total activity over the total volume or weight of the waste in the packaging is allowed (with constraints such as only allowing volume averaging if the waste contains small concentrated sources (<3.7 MBq or 0.1 mCi)).

The DOT does not allow such classification. The consolidating of LSA and SCO into a single packaging/container for shipment under the DOT HMR is allowed domestically only if classification of both the LSA and SCO are performed independent of each other and prior to consolidation. The consolidation of these two waste type, each identified by their own proper shipping name (PSN) and United Nations Identification Number (UN Number), is allowed in the HMR only as a "mixed content" package subject to 49 CFR 173.24a(c). Section 6.1.1 of NUREG-1608 provides for the consolidation of these two material types into one package without the need to meet the requirements of 49 CFR 173.24a(c) – this allowance, in essence, "acts like" a DOT Special Permit[34]. If each material type meets its respective classification criteria, the entire mix is allowed to be described using the PSN based on the LSA group provided the total package activity does not exceed $1A_2$.

[33] NUREG-1608, Section 4.2.4

[34] A Special Permit (49 CFR 107 SubPart B) is a document which authorizes a person to perform a function that is not currently authorized under the authority of the DOT hazardous materials regulations (49 CFR 100-185).

Any LSA/SCO consolidated package with a total package activity that exceeds $1A_2$ shall be described using the PSN and UN Number of the material type (SCO or LSA) contributing greatest to the A_2 fraction. A more rigorous classification requirement (e.g., quantitative and qualitative) is necessary when the total activity of the package exceeds $1A_2$. It is also important to recognize that the $1A_2$ activity level is applied to the package content and not individually to the LSA or SCO. Therefore, as a condition of consolidating LSA and SCO into a single package, if the total activity exceeds $1A_2$, a more rigorous characterization approach shall be applied to both the LSA and SCO.

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APPENDIX C: Considerations for Pre-Containerized Waste

When waste is in a container, available records of the contents may be inadequate for determination of LSA material and SCO. These types of containers may present many disadvantages when attempting to complete identification of LSA material and SCO, to include:

- The non-radioactive contents are present in an enclosed radioactive environment. Items that initially could have been within SCO limits may now be too contaminated to be SCO.
- The non-fixed, accessible contamination levels cannot be determined without opening the container and surveying the item.
- Accurate determination of the total activity is unknown, given the isotopes, daughter contributions, and matrix configurations.
- Destructive analysis, although optimal for identification of LSA material and SCO, may be unavailable, too costly, or too dangerous.

The steps used to manage these wastes will depend on many factors.

1. Consider how much pre-containerized waste will be disposed.
   How many containers are in a given generation lot? The easiest approach may be simply to determine the total activity and ship the containerized waste in a Type A or Type B packaging. If the scope includes many containers, destructive analysis on a sampling of containers may provide sufficient analytical data of similar contents to justify LSA or SCO.
2. Determine the radionuclide(s) present.
   Documentation to support LSA material and SCO shall be detailed enough to identify the isotopes in the material. This includes determining if the material consists of beta/gamma emitters, low toxicity alpha emitters, or other alpha emitters. The presence of fissile nuclides shall be determined and documented.

3. Describe the waste matrix.
   The matrix in each container shall be known. The description should establish if: a solid or liquid with uniform contamination throughout (i.e., LSA candidate); non-radiated items that are contaminated (i.e., SCO candidate); or both a definitive statement as to the contribution of each type. The description should clarify whether the contamination is uniform over the surface of the items. The presence of inner containers within the outer container should be documented. The use of a real-

time radiography device may be helpful in completing the description.

4. Measure the dose rate at all surfaces of the container.
   The measurement should be used to determine if the dose rate, based on the nuclide content, can be used to arrive at an activity level taking into account the matrix and shielding of the outer packaging. Document how close the dose rates are to the regulatory limits.

5. Calculate the A_2 fraction for each container.
   Wastes with greater than A_2, or close to the A_2 threshold (e.g., 0.9 A_2), require quantitative and qualitative assessment for LSA material or SCO determination.

6. Estimate the cost to determine if the waste meets the definition of LSA material and SCO.
   Making the determinations of LSA material or SCO may cost more than simply packaging and shipping in a Type A packaging. For waste that does not exceed A_2 value, the cost may preclude opening the container and evaluating the waste only to defend LSA material/SCO; packaging as A_2 may be advisable.

   When the waste is greater than A_2, repackaging will be necessary unless LSA material/SCO determination can be confirmed. The repackaging operations allow the contamination levels on the waste to be accurately assessed, the matrix defined, and the determination of LSA material/SCO is completed. When the waste is too greatly contaminated for LSA material or SCO, segregation of the waste into A_2 quantities can be accomplished.

7. Assess the content against the receiving facility's waste acceptance criteria.
   A determination should be made as to whether or not the waste, as packaged, meets the waste acceptance criteria. When it does not meet the waste acceptance criteria, processing will provide for determination as LSA material or SCO during removal of any prohibited items.

APPENDIX D: Information Needed for Identifying LSA Material and/or SCO

1. Identity of isotopes present (including daughter contributions)

2. Type of contamination (e.g., beta, gamma, low toxicity alpha, other alpha)

3. Total activity of packaged material or total activity of material per package (with error factor)

4. Matrix configuration (including varied matrices within a single packaging)

5. Distribution of radionuclides throughout the matrix

6. Type and mass of waste that is LSA candidate (e.g., solutions, powders, particulates, saturated solids, activated metals)

7. Type and mass of SCO-like wastes (<u>all</u> non-radioactive objects that are contaminated)

8. Surface area of the SCO candidate items (accessible and inaccessible surfaces)

9. Non-fixed contamination levels (beta/gamma/LTA and other alpha) on the accessible surfaces

10. Fissile nuclides: type, mass, distribution, configuration

11. Mass of all non-fissile material: net mass of waste and packaging tare mass

12. Mass of all lead, beryllium, graphite, and material enriched in deuterium

    All chemical information (corrosives, oxidizers, toxics, etc.)