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Contamination Surveys for Release of Material

J. S. Durham
D. L. Gardner
M. L. Johnson

May 1994

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
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CONTAMINATION SURVEYS FOR RELEASE OF MATERIAL

J. S. Durham, Ph.D.
D. L. Gardner[a]
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SUMMARY

This report describes, and presents the technical basis for, a methodology for performing instrument surveys to release material from radiological control, including release to controlled areas and release from radiological control. The methodology is based on a fast scan survey, a large-area wipe survey, and a series of statistical, fixed measurements. The methodology meets the requirements of the *U.S. Department of Energy Radiological Control Manual* (RadCon Manual) (DOE 1994) and DOE Order 5400.5 (DOE 1990) for release of material in less time than is required by a conventional scan survey. The confidence interval associated with the new methodology conforms to the draft national standard for surveys.

The methodology first requires evaluating the material for potential contamination. Material can be released without an instrument survey if its documented history ensures 1) that it has never been used or stored in an area controlled for contamination purposes (i.e., a contamination area [CA], high-contamination area [HCA], or airborne radioactivity area [ARA]), 2) that it has never come into contact with unsealed radioactive sources, and 3) that it has not been stored or used in a radiological buffer area (RBA) surrounding a CA, HCA, or ARA. If the material was used or stored in one or more of these areas, or if the material's history cannot be determined, an instrument survey is performed. The instrument survey consists of a fast scan of the entire accessible surface of the material at a rate that can measure, with 67% confidence, contamination at three times the guideline values tabulated in the RadCon Manual (DOE 1994). For Hanford instrumentation, the fast scan speed has been empirically determined to be 15 cm/s (6 in./s). Following the fast scan, a large-area wipe survey is made of the material area. A minimum material area of 29 cm^2 (4.5 $in.^2$) is required for large-area wipe surveys for beta-gamma contamination, and a minimum material area of 350 cm^2 (54 $in.^2$) is required for large-area wipe surveys for alpha contamination. After completing the large-area wipe survey, a series of twenty-two 5-sec fixed measurements is taken at random over the surface of the material. If no measurements are above background, the material may be released to radiologically controlled areas. If no measurements are above background, and the potential

radioactive contaminant is listed in Table IV-1 of DOE Order 5400.5 (DOE 1990), then the material may be released from radiological control. The fast scan measurements ensure, with 67% confidence, that none of the material's surface is contaminated above three times the guideline value. The statistical measurements ensure, with 67% confidence, that 95% of the material's surface is not contaminated above the minimum detectable activity for a 5-sec fixed measurement. If the surface area of the material is less than 4.6 m^2 (50 ft^2), the requirements for release of material tabulated in the RadCon Manual (DOE 1994) and DOE Order 5400.5 (DOE 1990) will be met. For material with a surface area larger than 0.56 m^2 (6 ft^2), the time required to perform an instrument survey using the new methodology is less than the time required to perform a conventional scan survey.

ACKNOWLEDGMENT

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1.0 INTRODUCTION

It is often necessary, and usually desirable, to release materials used within radiologically controlled areas at nuclear facilities for either controlled or uncontrolled use. Prior to their release, however, the materials must be evaluated for surface contamination. The goal of the evaluation process, which may include measurements, is to prevent the release of any material that contains surface contamination above the guideline values for surface contamination specified in the *U.S. Department of Energy Radiological Control Manual* (RadCon) (DOE 1994) and DOE Order 5400.5 (DOE 1990). (In the following text, the surface contamination guideline values listed in the RadCon Manual [DOE 1994] are denoted as the guideline values.) The guideline values are summarized in Table 1.

At the Hanford Site, material that leaves a radiologically controlled area is evaluated for the presence of surface contamination by means of an instrument survey. The survey requires passing an appropriate radiation detector over the material's surface at a rate of 5 cm/s (2 in./s) at a maximum distance from the surface of 0.6 cm (0.25 in.). The purpose of this paper is to provide the technical basis for a new material release methodology that meets the requirements of DOE orders and reduces the time required to release material.

This technical basis applies only to release of material with potential surface contamination. It does not apply to surveys of bulk contamination, such as soil; surveys of material that has been activated through irradiation; surveys of personnel and their effects; or surveys of buildings and other properties. Likewise, the methodology does not apply to automated radiation-detection equipment such as tool monitors and laundry monitors. For this document, material consists of equipment, furniture, tools, etc., that are portable or transferable.

The proposed material release methodology has four main components: material evaluation, scan survey for fixed contamination, large-area wipe survey for removable contamination, and statistical survey for fixed contamination. A logic diagram of the methodology is shown in Figure 1.

The methodology ensures, with 67% confidence, that the guideline values of DOE Order 5400.5 (DOE 1990) and the RadCon Manual (DOE 1994) are met. If no measurements are greater than background, the material may be released for controlled use. If no measurements are greater than background, and guideline values for the contaminant are listed in Table IV-1 in DOE Order 5400.5 (DOE 1990), the material may be released from radiological control.

Both the existing procedure and the proposed methodology have a 67% confidence interval associated with the measurements. A minimum confidence interval of 67% is recommended by both the American National Standards Institute (ANSI) draft standard ANSI 13.12 (ANSI 1978) and the Health Physics Society (HPS) Standards Committee[a] for performing radiation surveys. No other guidance is available on which to base a confidence interval for material release surveys.

For reasons detailed later, this methodology is applicable to material that has a surface area between 0.56 m^2 (6 ft^2) and 4.6 m^2 (50 ft^2). Material with a surface area of less than 0.56 m^2 (6 ft^2) can be surveyed faster, and with equal confidence, using a scan survey at a scan rate of 5 cm/s (2 in./s). Material that has a surface area greater than 4.6 m^2 (50 ft^2) must be separated into 4.6 m^2 (50 ft^2) partitions, and the methodology should be applied to each partition independently.

Inherent in the methodology is the ability of the instrument to measure contamination levels below the guideline values during a 5-second fixed measurement. Some radionuclides, notably tritium and some isotopes of iodine, cannot be adequately measured with portable instruments. The following methodology should not be applied when performing release measurements of material that has potentially been exposed to significant quantities of these radionuclides.

(a) Health Physics Society (HPS) Standards Committee. 1987. *Surface Radioactivity Guides for Materials, Equipment, and Facilities to be Released for Uncontrolled Use*. Draft.

TABLE 1. Summary of Contamination Values

NUCLIDE (See Note 1.)	**REMOVABLE (dpm/100 cm^2)** (See Note 2.)	**TOTAL (FIXED + REMOVABLE) (dpm/100 cm^2)** (See Note 3.)
U-natural, U-235, U-238 and associated decay products	1,000 alpha	5,000 alpha
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-129 (See Note 4.)	20	500
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-125, I-126, I-131, I-133	200	1,000
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above. Includes mixed fission products containing Sr-90.	1,000 beta-gamma	5,000 beta-gamma
Tritium organic compounds, surfaces contaminated by HT, HTO, and metal tritide aerosols (See Note 4.)	10,000	10,000

Notes:

1. The values in this table apply to radioactive contamination deposited on, but not incorporated into the interior of, the contaminated item. Where contamination by both alpha- and beta/gamma-emitting nuclides exists, the limits established for the alpha- and beta/gamma-emitting nuclides apply independently.
2. The amount of removable radioactive material per 100 cm^2 of surface area should be determined by swiping the area with dry filter or soft absorbent paper while applying moderate pressure and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. For objects with a surface area less than 100 cm^2, the entire surface should be swiped, and the activity per unit area should be based on the actual surface area. Except for transuranics, Ra-228, Ac-227, Th-228, Th-230, Pa-231, and alpha emitters, it is not necessary to use swiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual contamination levels are below the values for removable contamination.
3. The levels may be averaged over 1 m^2 provided the maximum activity in any area of 100 cm^2 is less than three times the values in Table 1.
4. Surface contamination guidelines for these radionuclides are reserved in DOE 5400.5 (DOE 1990). For these radionuclides, the surface contamination guidelines in the RadCon Manual (DOE 1994) are included. These guidelines refer only to release of material to controlled areas.

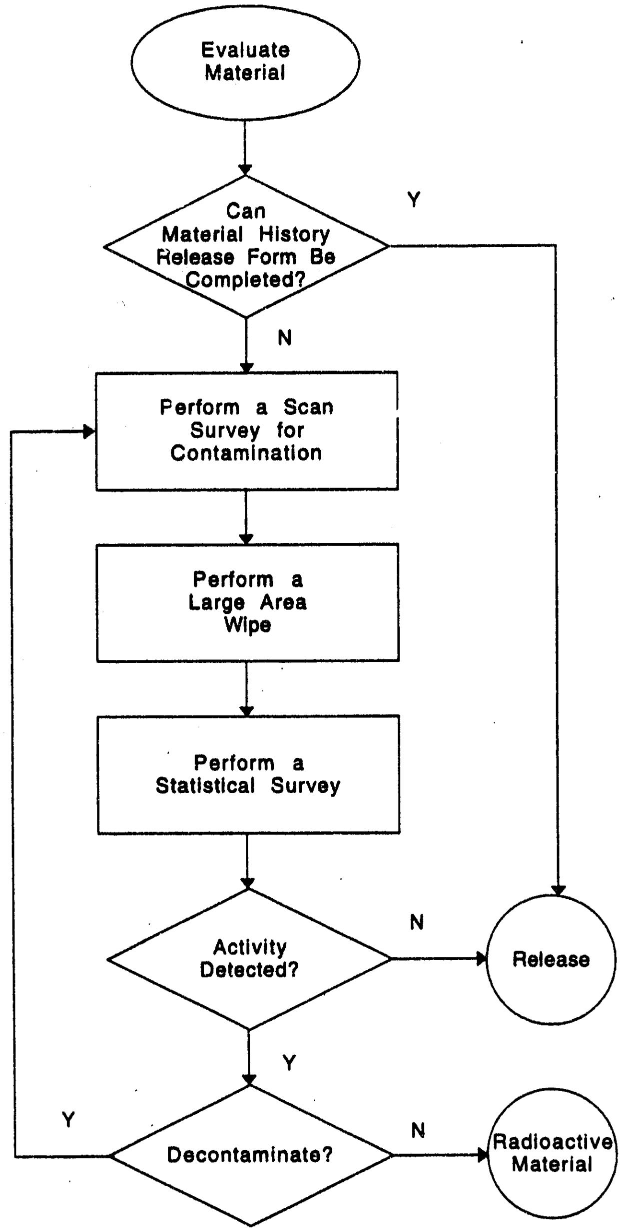

FIGURE 1. Protocol for Release of Materials

2.0 MATERIAL EVALUATION

Determination of the potential that material is contaminated is based on a process termed *material evaluation*. In this process, the evaluator considers previous known uses of the material, as well as typical uses and the environment in which the material was used. Material evaluation places the material into one of two categories: not potentially contaminated or potentially contaminated.

Material can be released without an instrument survey if 1) it has never been used or stored in an area controlled for contamination purposes (i.e., a contamination area [CA], high-contamination area [HCA], or airborne radioactivity area [ARA]), 2) it has never come into contact with unsealed radioactive sources, and 3) it has not been stored or used in a radiological buffer area (RBA) surrounding a CA, HCA, or ARA. This material may be considered to be nonradioactive material for which the RadCon Manual (DOE 1994) does not require an instrument survey. A material history release form is used to document the release of material that is known to be free of contamination by its history of use. If a material history release form cannot be completed, or if the history of the material is unknown, an instrument survey must be made of the material. Material released from RBAs around CAs, HCAs, or ARAs should also be evaluated using an instrument survey.

Material that is known to have resided in a CA, HCA, or ARA and that contains instrument-innaccessible areas may not require an instrument survey of the innaccessible areas. If a material history release form can be used to document that the innaccessible areas could not become contaminated without contaminating the accessible areas, then only a survey of the accessible areas is needed.

The material evaluation process should also consider the nuclides to which the material was potentially exposed. If the material was exposed to significant quantities of difficult-to-detect nuclides, including tritium, ^{125}I, or ^{129}I, this methodology should not be applied.

3.0 INSTRUMENT SURVEYS

A survey of material that is potentially contaminated is performed using a new survey methodology. This methodology is to perform a scan survey for fixed contamination of the surface area of the material, a large-area wipe survey of the surface area, and a statistical survey of the surface area. These surveys are discussed in detail in this section.

3.1 SCAN SURVEY FOR FIXED CONTAMINATION

A scan survey for fixed contamination requires passing the detector of an alpha and a beta/gamma survey instrument, as applicable, over the entire accessible surface of the material. The detector is moved at a constant rate that allows detection of contamination at a level equal to three times the guideline value. Note 3 in Table 1 states that the maximum activity in any 100-cm^2 area must be less than three times the guideline values. For Hanford instrumentation, the scan rate has been empirically determined to be 15 cm/s (6 in./s). The maximum source-to-detector distance during the scan should be 0.6 cm (0.25 in.). If a change in the audible output of the instrument is heard (that is, if the number of clicks increases noticeably), the area under the window of the instrument is resurveyed using a stationary measurement for 3 sec to 5 sec. If the increase does not persist, the scan continues. If the elevated counts persist, the material is contaminated and it should not be released. This procedure is followed until the entire surface of the material has been surveyed.

The scan survey for fixed contamination ensures that none of the surface of the material is contaminated above three times the guideline value. If no contamination above background is detected during the scan survey, a large-area wipe survey for removable contamination is performed. If contamination above background is detected, then decontamination of the material should be considered and the methodology described in this document is no longer applicable.

3.2 LARGE-AREA WIPE SURVEY FOR REMOVABLE CONTAMINATION

The purpose of a large-area wipe survey is to detect any removable surface contamination on the material. The surface of the material should be industrially clean (i.e., free of debris, grease, etc.) to reduce self-absorption of alpha contamination. The survey is performed by wiping the surface of the material. If only a beta/gamma survey is required, an absorbant material may be used. If an alpha survey is required, a nonabsorbant material should be used. Any removable contamination will be accumulated and concentrated on the wipe, thus increasing the probability of its detection. The wipe is then placed nearly in contact with the window of the appropriate beta/gamma- or alpha-measurement instrument for 5 sec, and the audible count rate is observed. If no increase above background is observed, then the wipe may be placed in contact with the detector. If no radioactivity above background is measured, a statistical survey for fixed contamination is performed. If radioactivity above background is measured, the material is contaminated and decontamination should be considered.

For most radionuclides, the guideline values for removable contamination are lower than the minimum detectable activity (MDA) of portable instruments. During a wipe survey, the surface area of the material must be large enough that the quantity of radioactivity collected on the swipe will be greater than the MDA of the instrument. Wipe surveys of areas smaller than this minimum surface area require extraordinary measurements, such as a scaler measurement. The minimum area for using a large-area wipe survey is given by

$$A_{minimum} = \frac{MDA}{GV} * 100 \text{ cm}^2 \qquad (1)$$

where GV is the guideline value for removable contamination. Because the wipe concentrates the contamination into an area smaller than the area of the detector, the MDA value derived for detection of a point source should be used in Equation 1. Values of the minimum area for surveys for removable beta/gamma and alpha contamination are provided in Section 3.4.

3.3 STATISTICAL SURVEY FOR FIXED CONTAMINATION

The survey for fixed contamination of material that is potentially contaminated is based on a statistical sampling of measurements obtained on the surface of the material. A series of 22 fixed, random measurements should be made over the area of the material. Each fixed measurement should be 5 sec in duration, with the detector in contact with the surface of the material. The maximum area of material that may be surveyed is based on the MDA of the instrument being used, as discussed below. The survey methodology should be used for both beta/gamma and alpha contamination, unless only one type of contaminant exists in the facility. If no measurements above background are observed, the material may be released from radiological control. The statistical survey provides assurance, with 67% confidence, that no more than 5% of the surface of the material is contaminated above the guideline values.

The fixed survey measurements should be chosen using random detector placements over the entire surface of the material. It may be prudent to bias some of the measurements toward those areas that are more likely to be contaminated, including handles, horizontal surfaces, stains, cracks, and other surface anomalies in which foreign material typically accumulates. This type of selection bias will further increase the confidence associated with the statistical survey method. A minimum of 22 fixed measurements must be maintained for all material that has a surface area greater than 0.56 m^2 (6 ft^2). For material that is smaller in area than 0.56 m^2 (6 ft^2), scanning at a rate that enables measurement of contamination at the guideline values (typically 5 cm/s [2 in./s]) is faster than the statistically based methodology.

3.4 DETERMINATION OF MAXIMUM AND MINIMUM MATERIAL AREAS

DOE Order 5400.5 (DOE 1990) states that "the levels may be averaged over 1 square meter provided the maximum activity in any area of 100 cm^2 is less than three times the [guideline] values." To meet this requirement, a maximum material area must be determined. The maximum material area, A_{max}, is based on the MDA of the instrument for a 5-second fixed count.

After following the above methodology, and if the MDA for a 5-second measurement is known (expressed as a fraction of the guideline value), then it can be stated that a maximum of 5% of the material is contaminated above the MDA but not above 3 times the guideline value. The remaining 95% of the material is contaminated at or below the MDA of the instrument. In the worst-case scenario, all of the contamination resides within a single square meter of the material's surface; 5% of the entire surface of the material is contaminated at three times the guideline value; and the remaining portion of the square meter is contaminated at the MDA of the instrument. For this worst-case scenario, the following equation can be written for a 1-m^2 area

$$3 \cdot GV \cdot x + MDA\,(1 - x) = GV \qquad (2)$$

where GV is the guideline value in dpm/cm^2, x is the fraction of 1 m^2 that is contaminated at 3 times the guidelines value, and MDA is the MDA in dpm/cm^2 for a 5-sec fixed measurement. The first term in Equation 2 ($3 \cdot GV \cdot x$) represents the fraction of the 1-m^2 area that is contaminated at 3 times the guideline value. The second term in Equation 2 [MDA(1-x)] is the remaining fraction of the 1-m^2 area that is contaminated at the MDA value. Finally, the right side of Equation 2 is the guideline value averaged over 1 m^2. Rearranging Equation 2 and solving for x gives

$$x = \frac{1 - \frac{MDA}{GV}}{3 - \frac{MDA}{GV}} . \qquad (3)$$

Because x represents 5% of the total surface area of the material in m^2, the maximum area, A_{max}, is given by

$$A_{max} = \frac{1-\frac{MDA}{GV}}{0.05\left(3-\frac{MDA}{GV}\right)}. \quad (4)$$

Equations 1 and 4 establish limits on the area of the material to which the statistically based methodology can be applied, and these limits are based on the measurement capabilities of the instruments used in performing material release surveys. Measurements of the detection capabilities of Hanford instrumentation for various radionuclides have been completed for both point and distributed sources. For most of the radionuclides listed in the RadCon Manual (DOE 1994), Table 2 gives the minimum material area for surveys for removable contamination and Table 3 gives the maximum material area for surveys for fixed contamination. Note that the difference in minimum and maximum material areas between separated $^{90}Sr/^{90}Y$ and $^{90}Sr/^{90}Y$ as a mixed-fission product are a result of different guideline values for the two forms. In addition, the guideline values for separated $^{90}Sr/^{90}Y$ can only be measured using a 100-cm^2 gas proportional counter, and this instrument is recommended for use during surveys for separated $^{90}Sr/^{90}Y$ at the Hanford Site.

If separated ^{99}Tc is excluded, limits on the area of the material can be determined based on the data in Table 2. Because ^{99}Tc and $^{90}Sr/^{90}Y$ are seldom encountered in their separated forms, excluding them from the general methodology is warranted. The most limiting material area for applying the statistically based methodology to surveys for fixed contamination is 4.6 m^2 (50 ft^2). For surveys for removable beta/gamma contamination, the most limiting material area is 41 cm^2 (4.5 $in.^2$). For surveys for removable alpha contamination, the most limiting material area is 350 cm^2 (4 $in.^2$).

TABLE 2. Minimum Material Area for Surveys for Removable Contamination

Nuclide	MDA (point source), dpm/100 cm^2	Minimum Material Area, cm^2 ($in.^2$)
U-natural, U-235, U-238	70	7 (1.1)
Pu-239, Ra-226, Th-230, Th-228, Pa-231, Ac-227	70	350 (54)
Th-natural, Th-232, Ra-223, Ra-224, U-232	70	35 (5.4)
Separated Sr/Y-90	210[a]	105 (16)
Sr/Y-90	260	26 (4.0)
Tc-99	410	41 (6.4)
Cs-137	290	29 (4.5)

(a) MDA for a 100-cm^2 gas proportional counter.

TABLE 3. Maximum Material Area for Surveys for Fixed Contamination

Nuclide	MDA (distributed source), dpm/100 cm^2	Maximum Material Area, m^2 (ft^2)
U-natural, U-235, U-238	140	6.5 (71)
Pu-239, Ra-226, Th-230, Th-228, Pa-231, Ac-227	140	5.3 (57)
Th-natural, Th-232 Ra-223, Ra-224, U-232	140	6.0 (65)
Separated Sr/Y-90	210[a]	5.7 (61)
Sr/Y-90	1700	5.0 (54)
Tc-99	2600	3.9 (42)
Cs-137	1900	4.7 (51)

(a) MDA for a 100-cm^2 gas proportional counter.

4.0 DISCUSSION

The goal of the proposed methodology is to meet the requirements for releasing material in DOE Order 5400.5 (DOE 1990) and the RadCon Manual (DOE 1994) while reducing the time that is currently required to survey material at 5 cm/s (2 in./s). For most radionuclides, a survey using a scan rate of 5 cm/s (2 in./s) will measure contamination at the guideline values with a confidence of 67%. A confidence interval of 67% is recommended by both ANSI and HPS for radiation surveys. The statistically based me.hodology significantly reduces the time required to survey the material.

Using the proposed methodology will eliminate the dependence on a slow, time-consuming scan rate. After using the methodology, it can be stated, with 67% confidence, that no 100-cm^2 area of the material is contaminated above three times the guideline value, and that the contamination level averaged over any 1 m^2 is below the guideline value. By biasing the statistical survey measurements toward those areas that are more likely to be contaminated, the confidence associated with the methodology is further increased. Thus, for the "unreserved" radionuclides listed in DOE Order 5400.5 (DOE 1990) (with the exception of difficult-to-detect radionuclides), all of the requirements for release are met and the material may be released from radiological control. Because the RadCon Manual (DOE 1994) contains guideline values for the "reseved" radionuclides in DOE Order 5400.5 (DOE 1990), material that may have been exposed to reserved radionuclides may be released for controlled use by following the proposed methodology.

In order to compare the time required to survey a hypothetical piece of material using the traditional scan survey and the statistically based methodology for both 67% and 95% confidence, the following exercise was completed. Consider the survey of a flat piece of material that is 13 cm (5 in.) wide. This width is chosen because it corresponds to the largest dimension of the window of a Hanford portable alpha monitor (window area of 50 cm^2) and will require only a single pass of the alpha detector. The estimates were made by assuming that the material is surveyed by both an alpha probe and a pancake G-M probe (window area of 15 cm^2), and that the G-M probe requires three passes for each pass of the alpha probe (to allow for an overlap of about 25% between passes). Table 3 presents a comparison of using the conventional scan procedure and the statistical methodology for both 67% and 95% confidence. The statistical survey with 95% confidence requires 59 fixed measurements (5-min survey time per instrument) and a fast scan rate of 5.3 cm/s (2 in./s). The statistical survey with 67% confidence requires 22 fixed measurements (2-min survey time per instrument) and a fast scan rate of 15 cm/s (6 in./s).

In addition to the previously discussed hard-to-detect radionuclides, a number of the methodologies are not able to measure the guideline values for several radionuclides. The guideline values for ^{99}Tc cannot be measured using a 5-sec fixed measurement at the 95% confidence level. The guideline values for ^{230}Th and ^{231}Pa cannot be measured using a 5 cm/s (2 in./s) scan rate with 67% confidence. Finally, a scan rate of 2.5 cm/s (1 in./s) cannot measure the guideline values for ^{230}Th, ^{231}Pa, ^{239}Pu, ^{228}Th, ^{226}Ra, or ^{227}Ac with 95% confidence. Both the 1-in./s scan survey and the statistically based survey are able to measure the guideline values for all radionuclides with 67% confidence, with the exception of the previously noted hard-to-detect radionuclides.

The results of the comparison, which are presented in Table 3, show that the statistical method is significantly faster than the scanning method. It must be noted that both the 1-in./s scan survey and the statistical survey meet the requirements of the RadCon Manual (DOE 1994) with 67% confidence. Table 3 also shows that a statistically based survey with 95% confidence requires nearly twice the time as a statistically based survey with 67% confidence. The data suggest that the increased time required to perform a 95% survey, coupled with the inability to measure the guideline values for all radionuclides listed in Table 2, is not justified.

TABLE 3. Comparison of Survey Times for Different Survey Methodologies

Material Area	2-in./s Scan	1-in./s Scan	67% Statistical	95% Statistical
0.56 m^2 (6 ft^2)	5.8 min	12 min	5.9 min	16 min
2.3 m^2 (25 ft^2)	24 min	48 min	12 min	34 min
4.6 m^2 (50 ft^2)	48 min	96 min	20 min	58 min

5.0 CONCLUSION

Implementation of the proposed methodology with a confidence interval of 67% will meet the material release requirements in DOE Order 5400.5 (DOE 1990) and the RadCon Manual (DOE 1994). The material evaluation process will allow material that has not been exposed to contamination to be released from radiological control without a survey. For potential radioactive contaminants that are not reserved in DOE Order 5400.5 (DOE 1990), the methodology will allow material to be released from radiological control. For other radionuclides, with the exception of some difficult-to-detect radionuclides, material may be released for controlled use. Compared with current techniques, the proposed methodology will reduce the amount of time required to perform surveys.

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