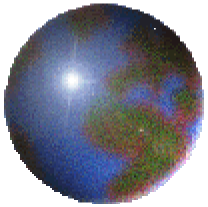

MARSSIM Implementation at University and Medical Research Facilities

Professional Enrichment Program

Health Physics Society meeting in Tampa, FL

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Introduction

- Preliminary considerations for MARSSIM final status survey design in a laboratory:
  - identifying contaminants, establishing DCGLs, classifying areas, identifying survey units, selecting survey instruments and techniques, and physical characteristics of the facility
- Example MARSSIM FSS design at a laboratory

Identifying Contaminants

- Review routine health physics surveys, sink disposal logs, and material receipt forms
- Review the broad scope license—what radionuclides used in lab research?
- Common radionuclides include H-3, C-14, I-125, P-32, S-35, and gamma-emitting, short-lived microspheres used primarily for tracer studies

Identifying Contaminants (cont.)

- Sampling and analysis at locations of contamination to ID radionuclides (smears, scrapings, residue)
- Possible to rule out the presence of a number of short-lived radionuclides, e.g., P-32 (14 day), S-35 (87 day), and I-125 (60 day) due to radioactive decay

Historical Guidelines and DCGLs

- Labs continue to cleanup to historic criteria—Regulatory Guide 1.86, or the more appropriate NRC 1987 guidance document for non-reactor licenses
- 5,000 dpm/100 cm^2 for beta/gamma emitters; 100 dpm/100 cm^2 for I-125

Historical Guidelines and DCGLs (cont.)

- NRC promulgated License Termination Rule in 10 CFR Part 20 in July 1997; unrestricted release criterion 25 mrem/y
- NRC has issued NUREG-1727, NMSS Decommissioning Standard Review Plan
  - Preparation of decommissioning plans (DP)
  - Most lab D&D projects do not require submittal of DP

DCGLs for Building Surface Contamination

- November 18, 1998 FRN provided a screening DCGLs for some radionuclides
- App. B of NUREG-1757 consolidated decommissioning guidance has DCGLs
- NRC suggests use of modeling codes DandD Ver. 2 or RESRAD-Build 3.1

Screening DCGLs Based on 25 mrem/y Dose Criterion

- H-3 1.2E+08 dpm/100 cm^2
- C-14 3.7E+06 dpm/100 cm^2
- S-35 1.3E+07 dpm/100 cm^2
- I-129 35,000 dpm/100 cm^2
- Using DandD Ver. 2 to determine DCGL:

  I-125 6.9E+05 dpm/100 cm^2

Huge Difference from Historic Guidelines!!

Establishing DCGLs

- Once DCGLs selected, how will DCGLs be applied for multiple radionuclides?
- Determine the contaminants present in the lab, and their relative ratios
- Gross activity DCGL (for surface activity):

$$DCGL = \frac{1}{f_1 / DCGL_1 + f_2 / DCGL_2 + \ldots f_n / DCGL_n}$$

Establishing DCGLs with H-3

- Tritium often assessed via wet smears
- Low energy beta difficult to measure in the field—mixed results using windowless gas proportional detector
- Strategy: Scale the tritium to the total activity present & calculate gross activity DCGL; requires good HSA & characterization to justify relative ratios

Example—Gross Beta DCGL

- Given C-14, H-3, and S-35 DCGLs and relative ratios as follows:

C-14	3.7E6 dpm/100 cm^2	35%
H-3	1.2E8 dpm/100 cm^2	40%
S-35	1.3E7 dpm/100 cm^2	25%

Example—Gross Beta DCGL

- Gross beta DCGL is calculated:

$$\frac{1}{0.35/3.7E6+0.4/1.2E8+0.25/1.3E7}=8.5E6\,dpm/100cm2$$

- Total efficiency should be weighted for exact radionuclide mixture; this will likely include a 40% component of zero for H-3

Classifying Areas

- Lab areas are classified according to their contamination potential (Class 1, 2, or 3)

- Scoping and characterization surveys build on the HSA data, providing information on the surface activity levels

Identifying Survey Units

- Class 1 survey unit might comprise a single room, or Class 2 survey unit might include several lab rooms located along a common corridor
- MARSSIM guidance on survey units (SU):

  1) SU should have similar contamination potential

  2) SU sizes should be consistent with dose modeling areas used to generate DCGLs

  3) suggested survey unit sizes in MARSSIM (e.g., 100 m^2 for Class 1)

Field and Lab Survey Instrumentation

- Gas proportional and GM detectors used for beta emitters (C-14, S-35)
- Thin NaI and CsI detectors for I-125 (2.54 cm diam x 1 mm thick)
- Windowless gas proportional for H-3?
- Large area gas proportional floor monitors
- Liquid scintillation counters (smears)

Survey Procedures—Scans

- Performed on building surfaces and equipment by passing the detectors slowly over the surface to find hot spots
- Floor monitors (~550 cm^2) and hand-held gas proportional and GM detectors to scan floors, walls and equipment
- Need to calculate scan MDCs

Survey Procedures—Surface Activity Measurements

- Primary data to release laboratory
- Gas proportional & GM detectors with ratemeter-scalers (integrated counts)
- Average background determined for each surface material type in non-impacted area
- Measurements performed at random-systematic and judgmental locations

ISO-7503 METHODOLOGY

- ISO-7503-1 "Evaluation of Surface Contamination-Part 1: Beta Emitters and Alpha Emitters"
- Total efficiency based on instrument and surface efficiency components:

$$A_S = \frac{R_{S+B} - R_B}{(\varepsilon_i)(\varepsilon_S)(W)},$$

where:

ε_i is the instrument or detector efficiency,

ε_s is surface efficiency,

W is the physical probe area

DETERMINATION OF ε_i

- ε_i is determined similarly to current practice, except that detector response, in cpm, is divided by the 2π surface emission rate of the calibration source (not source activity in dpm)
- ε_i is calculated from the 2π surface emission rate of the calibration source, that is subtended by the physical probe area of the detector ($q_{2\pi,sc}$):

$$\varepsilon_i = \frac{R_{S+B} - R_B}{q_{2\pi,sc}}$$

DETERMINATION OF ε_s

- ε_s is determined either by experimentation, or by simply selecting appropriate values based on the radiation type and energy

- Recommendations of ISO-7503:
  - ε_s equals 0.5 for maximum beta energies, $E_\beta > 0.4$ MeV (e.g., Tl-204, SrY-90)
  - ε_s equals 0.25 for 0.15 MeV $< E_b <$ 0.4 MeV and alphas (e.g. C-14, Pu-239)

Survey Procedures—Removable Surface Activity

- Removable tritium activity levels collected at each direct measurement location
- Use a moist (wet) smear (e.g., using numbered filter paper disks, cotton balls)
- Wipe an area of 100 cm^2
- Place smear in a labeled liquid scintillation vial (20 mL glass vial)

Accessibility to Lab Areas

- Presence of hoods, storage cabinets and equipment can restrict access to lab building and equipment surfaces
- May be beneficial to remove lab benches and hoods, to obtain access to potentially contaminated floors and walls

Accessibility to Lab Areas (cont.)

Location of Judgment Samples

- Judgment locations include floors (near benches and waste containers), hoods and ductwork, sinks and drains, and lab benches
- Wall/floor and bench/floor interfaces
- Beneath tile or other floor coverings
- Locations identified by scanning

Judgment Measurements—Sink and Bench Top

Judgment Measurements—Floor Near Bench

Decontamination and Remedial Action Support Surveys

- D&D activities include simple washing and wiping surfaces to dismantlement and equipment removal, including hoods and sink drain lines
- Remedial action support survey (RASS) assess success of decontamination activities
- Results of RASS surveys are used to update the radiological status of the laboratory (e.g., mean and std dev of contamination in survey unit)

Final Status Survey

- Final status survey in MARSSIM design relies on DQO process for data collection
- Sample size calculated that can statistically demonstrate compliance with the derived concentration guideline levels (DCGLs)
- Final status survey has both a statistical (unbiased) and judgmental (biased) component—data evaluated separately

Final Status Survey (cont.)

- Null hypothesis (H_0): Residual radioactivity **exceeds** the release criteria
  - H_0 is treated like a baseline condition, assumed to be true in the absence of strong evidence to the contrary
- Decision errors occur when H_0 is rejected when it is true (Type I), or when H_0 is not rejected (accepted) when it is false (Type II)

Final Status Survey (cont.)

- Two statistical tests are used to plan and evaluate final status survey data
  - Wilcoxon Rank Sum (two-sample test)
  - Sign Test (one-sample test)
- Use Sign test when surface activity assessment performed with average background subtracted from each measurement

Final Status Survey Design for a Laboratory Room

- Single laboratory room is being decommissioned
- HSA review of inventory records and discussions with principal investigator indicates H-3 was used twice as much as C-14 for experiments
- I-125 was used occasionally (last use was several months ago)—cannot be ruled out completely due to radioactive decay
- Relative ratios used for the FSS survey design are 60% H-3, 30% C-14, and 10% I-125

Physical Characteristics of Lab

- The floor, lower walls and bench in this lab have been classified as a Class 1 survey unit
- Total surface area of survey unit is 230 m^2
- Floor surface is comprised of poured concrete covered with vinyl tile
- Walls are comprised of drywall
- Lab bench was decontaminated and remains in the room; hood and storage cabinets were removed

Final Status Survey Strategy

- The Sign test will be used for to demonstrate complianceCaverage background will be subtracted from each gross measurement of surface activity
- DCGLs: 1.2E8 dpm/100 cm^2 for H-3
  3.7E6 dpm/100 cm^2 for C-14
  6.9E5 dpm/100 cm^2 for I-125

Final Status Survey Strategy (cont.)

- Surface activity in dpm/100 cm^2 will be compared to the DCGL to demonstrate compliance
- Moistened smears to measure removable tritium activity levels will be collected at each random and judgmental measurement location
- Removable tritium results will be individually compared to 10% of the tritium $DCGL_W$ (the screening DCGL is modeled based on a removable fraction of 10%)

Gross Beta DCGL

- Gross beta DCGL must consider relative ratios of H-3, C-14, and I-125:

$$\frac{1}{0.6/1.2E8 + 0.3/3.7E6 + 0.1/6.9E5} = 4.3E6\, dpm/100cm2$$

- Gross beta DCGL = 4.3E6 dpm/100 cm^2

Survey Instrument DQOs

- Gas proportional detector used for surface activity measurements
- Static MDC should be less than 50% DCGL

$$MDC = \frac{3 + 4.65\sqrt{C_B}}{\varepsilon_i \varepsilon_s T} \qquad (in\ dpm/100\ cm^2)$$

- Instrument efficiency for C-14 was 0.21; assumed to be zero H-3 and I-125

Survey Instrument DQOs (cont.)

- Total efficiency is weighted according to the relative ratios; $\varepsilon_{weighted,tot}$ equals: $(0.6)(0)+(0.3)(0.21)(0.25)+(0.1)(0) = 0.016$
- Average background counts on vinyl floor (348 cpm) & drywall (286 cpm)
- MDC was 4,500 dpm/100 cm^2 for a 1-min count (~0.1% of $DCGL_W$)

Survey Instrument DQOs for Scanning

- Scan MDC for scanning instruments can be calculated using NUREG-1507 approach
- Scan MDC is a function of background level, scan rate, hot spot size, and human factors
  - Background levels for floor monitor range from 800 to 1400 cpm
  - Background levels for hand-held gas proportional detector range from 250 to 450 cpm

Scan MDC Determination

- The minimum detectable count rate (MDCR) in observation interval is determined:

$$MDCR_i = \frac{d' \sqrt{b_i}}{i \sqrt{p}}$$

- where:

  b_i = Background counts in observation interval

  d' = Detectability index, based on acceptable correct detection rate and false positives

  p = Surveyor efficiency relative to ideal observer (taken to be 0.5 based on experimentation)

Scan MDC for Hand-held Gas Proportional Detector

- Scan rate provides for observation interval, i, equal to 2 sec (scan rate and estimated hot spot size yields obs interval)
- Detector parameters: Bkg = 250 cpm and weighted efficiency is 0.016

Scan MDC for Hand-held Gas Proportional Detector (cont.)

- d' = 2.32 for 95% true detection and 25% false positives, and surveyor efficiency (p) is 0.5:

$$MDCR = \frac{2.32\sqrt{8.3}}{\sqrt{0.5}\,(2\sec)} = 4.7\, c/s \text{ or } 280\, cpm$$

and

$$Scan\ MDC = \frac{MDCR}{\varepsilon_{\text{tot}}} = \frac{280\ cpm}{(0.016)} = 18{,}000\ dpm/100\ cm^2$$

Scan MDC Summary

- Scan MDC ranges were as follows:

  Hand-held gas proportional detector:

  18,000 to 24,000 dpm/100 cm^2

  Floor monitor: 32,000 to 42,000 dpm/100 cm^2
- Since these scan MDCs are well below the $DCGL_W$, no additional measurements in this Class 1 survey unit are required

Sign Test —Number of Measurements

- Number of data points based on:
  - Gross beta DCGL
  - Expected standard deviation of contamination in the survey unit
  - Acceptable probability of making Type I and Type II decision errors
  - Lower bound on the gray region (LBGR)

Gross Beta DCGL in Units of cpm

- Gross beta DCGL is 4.3E6 dpm/100 cm^2
- Gross beta DCGL in cpm:

$(4.3E6\ dpm/100\ cm^2)(0.016)(126/100) = 87{,}000\ cpm$

Expected Radiological Conditions in Survey Unit

- Characterization (or RASS) data used for planning:
  - Survey Unit

    Gross β   1622 ± 512 cpm (1σ)

  - Reference Area (vinyl floor)

    Gross β   348 ± 43 cpm (1σ)

Calculate the relative shift—Δ/σ

- LBGR set at expected net concentration:
  (1622 - 348) = 1274 cpm

- Based on characterization survey data, the expected mean concentration in the lab survey unit is 1274 cpm (significantly less than the $DCGL_W$)

Standard Deviation in the Survey Unit

- Variability for measurements should consider that Sign test involves subtracting mean background from gross measurement:

$$\sigma_{total} = \sqrt{\sigma_s^2 + \sigma_r^2}$$

- Gross beta standard deviation:

$$\sigma_{total\,\beta} = \sqrt{512^2 + 43^2} = 514\ cpm$$

Determine Sign Test Sample Size

- The relative shift is calculated:

$\Delta/\sigma = (87{,}000 - 1274)/514 = 167$

- Use a relative shift of 3
- Type I and II decision errors set at 0.05
- MARSSIM Table 5.5 provides N = 14
- Statistical power for this survey design ~100% at expected concentration in SU

Integrated Final Status Survey

- 100% floor, lower wall and bench scans
- Indications of elevated radiation levels will be subject to judgmental measurements, both direct measurement & tritium smear
- 14 sample locations selected randomly; 1-min direct measurement and H-3 smear at each location
- Scale map of the lab room (including floor, lower walls, and bench) to facilitate sample placement

Data Quality Assessment

- All 14 systematic direct measurements were less than the gross beta $DCGL_W$
- Null hypothesis is rejected; the survey unit passes w/o formally conducting the Sign test
- Tritium smear results ranged from -30 to 12,000 dpm/100 cm^2, indicating level of removal tritium contamination was also well below 10% of the $DCGL_W$

Surface Activity Levels

Gross Measurement (cpm)	Surface Material	Gross Beta Surface Activity (dpm/100 cm^2)
458	vinyl floor	5,500
1034	vinyl floor	34,000
2305	vinyl floor	97,000
366	drywall	4000
267	drywall	-940
881	bench top	26,000
1546	vinyl floor	59,000
907	vinyl floor	28,000
309	drywall	1,100
442	vinyl floor	4,700
1123	vinyl floor	38,000
2709	vinyl floor	120,000
344	drywall	2,900
660	vinyl floor	15,000

Data Quality Assessment (cont.)

- Scanning resulted in the identification of two hot spots on the floor, and one in the hood ductwork
- All judgmental direct measurements and tritium smears were well below the release limits