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Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME)

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ABSTRACT

The *Multi-Agency Radiation Survey and Assessment of Materials and Equipment* manual (MARSAME) is a supplement to the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) providing information on planning, conducting, evaluating, and documenting radiological disposition surveys for the assessment of materials and equipment. MARSAME is a multi-agency consensus document that was developed collaboratively by four Federal agencies having authority and control over radioactive materials: Department of Defense (DOD), Department of Energy (DOE), Environmental Protection Agency (EPA), and Nuclear Regulatory Commission (NRC). The objective of MARSAME is to provide a multi-agency approach for planning, performing, and assessing disposition surveys of materials and equipment, while at the same time encouraging an effective use of resources.

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ACRONYMS AND ABBREVIATIONS

AL	action level
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BKGD	background
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
cpm	counts per minute
cps	counts per second
CSM	conceptual site model
CSU	combined standard uncertainty
CZT	cadmium zinc telluride
DAC	derived air concentration
DCGL	derived concentration guideline level
DL	discrimination limit
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
dpm	disintegrations per minute
DQA	data quality assessment
DQO	data quality objective
EMC	elevated measurement comparison
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EU	European Union
EZ	exclusion zone
FIDLER	field instrument for the detection of low-energy radiation
FRER	fluence rate to exposure rate
GM	Geiger Mueller
HASP	health and safety plan
HEU	high-enriched uranium
HPGe	high-purity germanium
HPS	Health Physics Society
HSA	Historical Site Assessment
HPSR	Health Physics Society Report
HWP	hazard work permit
IA	initial assessment
IAEA	International Atomic Energy Agency
IEEE	Institute of Electrical & Electronics Engineers
ISGS	in situ gamma spectroscopy
ISO	International Organization for Standardization

JSA	job safety analysis
LBGR	lower bound of the gray region
LEU	low-enriched uranium
LSA	low specific activity
LSC	liquid scintillation cocktail
M&E	materials and equipment
MARLAP	Multi-Agency Radiological Laboratory Analytical Protocols manual
MARSAME	Multi-Agency Radiation Survey and Assessment of Materials and Equipment manual
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCA	multi-channel analyzer
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
$MDCR_{surveyor}$	MDCR by a less than ideal surveyor
MDER	minimum detectable exposure rate
MQC	minimum quantifiable concentration
MQO	measurement quality objective
NARM	naturally occurring and accelerator-produced radioactive material
NCRP	National Council on Radiation Protection and Measurements
NIST	National Institute of Science and Technology
NJBER	New Jersey Bureau of Environmental Radiation
NORM	naturally occurring radioactive material
NRC	Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Commission technical report prepared by NRC staff
NUREG/CR	Nuclear Regulatory Commission technical report prepared by NRC contractor
ORISE	Oak Ridge Institute for Science and Education
OSHA	Occupational Safety and Health Administration
OSWER	EPA Office of Solid Waste and Emergency Response
PCB	polychlorinated biphenyl
pH	hydrogen ion concentration (acidity or basicity)
PIC	pressurized ion chamber
PPE	personal protective equipment
PVC	polyvinylchloride
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RCA	radiological control area
RCRA	Resource Conservation and Recovery Act
RCSU	relative combined standard uncertainty
RDR	relative detector response
RESRAD	RESidual RADioactivity computer code (exposure pathway model)
ROC	radionuclide of concern
RTG	Radioisotopic Thermoelectric Generator

RWP	radiation work permit
SCO	surface-contaminated object
SI	International System of Units (Système International d'Unités)
SOP	standard operating procedure
TEDE	total effective dose equivalent
TENORM	technologically enhanced naturally occurring radioactive material
TRU	transuranic
UBGR	upper bound of the gray region
UCL	upper confidence limit
UMTRCA	Uranium Mill Tailings Radiation Control Act
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USEPA	United States Environmental Protection Agency
U.S.	United States
WRS	Wilcoxon Rank Sum

SYMBOLS, NOMENCLATURE, AND NOTATIONS

<	less than
>	greater than
≤	less than or equal to
≥	greater than or equal to
°	degrees (angle or temperature)
%	percent
$1-\beta$	statistical power of a hypothesis test
α	Type I decision-error rate
α_Q	quantile test ($\alpha_Q = \alpha/2$)
a	half-width of a rectangular or triangular probability distribution
A	area
A	overall sensitivity of a measurement
Ac	actinium (isotope listed: ^{228}Ac)
AL_i	action level value an individual radionuclide (i = 1, 2, …, n)
$AL_{meas,mod}$	modified action level for the radionuclide being measured when it is used as a surrogate for other radionuclide(s)
AL_{meas}	action level for the radionuclide being measured
AL_{infer}	action level for the inferred radionuclide (in surrogate measurements)
Am	americium (isotope listed: ^{241}Am)
β	Type II decision-error rate
b	background count rate
b_i	the average number of counts in the background interval (scanning)
Be	beryllium (isotope listed: ^{7}Be)
Bi	bismuth (isotopes listed: ^{210}Bi, ^{212}Bi, ^{214}Bi)
Bq	becquerel
C	carbon (isotope listed: ^{14}C)
C	radionuclide concentration or activity
Ci	curie
C_i	concentration value an individual radionuclide (i = 1, 2, …, n)
c_i	sensitivity coefficient
$c_i\mu(x_i)$	component of the uncertainty in y due to x_i
C_{infer}/C_{meas}	ratio of amount of the inferred radionuclide to that of the measured surrogate radionuclide
°C	degrees Celsius
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
Cd	cadmium (isotope listed: ^{109}Cd)
Co	cobalt (isotopes listed: ^{57}Co, ^{60}Co)
Cs	cesium (isotope listed: ^{137}Cs)
CsI(Tl)	cesium iodide (thallium activated)
Δ	shift (width of the gray region, UBGR–LBGR)

Δ/σ	relative shift
d	parameter in the Stapleton Equation for the critical net signal
d'	detectability index (scanning)
ε_i	instrument efficiency
ε_s	surface efficiency for surveyed media
eV	electron-volt
E_γ	energy of a gamma photon of concern in kiloelectron-volts (keV)
E_i	energy of a photon of interest
°F	degrees Fahrenheit
f_i	relative fraction of activity contributed by radionuclide *i* to the total
ft	foot (feet)
ft^3	cubic foot (feet)
Fe	iron (isotope listed: ^{55}Fe)
g	gram
GBq	gigabecquerel (1×10^9 becquerels)
GG_{AL}	gross gamma action level
h	hour
H	hydrogen (isotope listed: ^3H [tritium])
H_0	null hypothesis
H_1	alternative hypothesis
i	observation time interval length (scanning)
I	iodine (isotopes listed: ^{123}I, ^{125}I, ^{131}I)
in	inch
Ir	iridium (isotope listed: ^{192}Ir)
k	coverage factor for the expanded uncertainty, U
K	potassium (isotope listed: ^{40}K)
kBq	kilobecquerel (1×10^3 becquerels)
keV	kiloelectron-volt (1×10^3 electron-volts)
kg	kilogram
k_Q	multiple of the standard deviation defining y_Q, usually chosen to be 10
L	grid size spacing
L	liter
lb	pound
µ	micro (10^{-6})
μ	theoretical mean of a population distribution
$(\mu_{en}/\rho)_{\text{air}}$	mass energy absorption coefficient in air centimeters squared per gram (cm^2/g)
µR	microroentgen (1×10^{-6} roentgen)
m	number of reference measurements (WRS test or Quantile test)
m	meter
m^2	square meter
MeV	megaelectron-volt (1×10^6 electron-volt)
mrem	millirem (1×10^{-3} rem)

mSv	milliseivert (1×10^{-3} Sv)
n	number of survey unit measurements (WRS test or Quantile test)
N	sample size, i.e. number of data points (or samples) for the Sign test
n_{EA}	survey unit area divided by the maximum area corresponding to the area factor, which yields the number of measurements needed so the scan MDC is adequate
Na	sodium (isotope listed: ^{22}Na)
NaI(Tl)	sodium iodide (thallium activated)
Ni	nickel (isotope listed: ^{63}Ni)
Np	neptunium (isotope listed: ^{237}Np)
ξ_B	non-Poisson variance component of the background count rate correction
p	coverage probability for expanded uncertainty, also used for efficiency of a less than ideal surveyor (scanning)
P	probability of interaction between radiation and a detector
Pa	protactinium (isotopes listed: ^{234}Pa, ^{234m}Pa)
PA	probe area
Pb	lead (isotopes listed: ^{212}Pb, ^{214}Pb)
PC	personal computer
pCi	picocurie (1×10^{-12} curies)
Pm	promethium (isotope listed: ^{147}Pm)
Po	polonium (isotopes listed: ^{210}Po, ^{212}Po, ^{214}Po, ^{216}Po)
Pu	plutonium (isotopes listed: ^{238}P, ^{239}Pu, ^{240}Pu, ^{241}Pu)
q	critical value for statistical tests (Table A.3, Table A.4)
ρ	density
$\rho(X_i,X_j)$	correlation coefficient for two input quantities, X_i and X_j
R	ratio
R	roentgen (exposure rate)
Ra	radium (isotopes listed: ^{224}Ra, ^{226}Ra, ^{228}Ra)
R_B	mean background count rate
R_I	mean interference count rate
Rn	radon (isotopes listed: ^{220}Rn, ^{222}Rn)
$r(x_i,x_j)$	correlation coefficient for two input estimates, x_i and x_j
σ	theoretical total standard deviation of the population distribution being sampled
σ_M	theoretical measurement standard deviation of the population distribution being sampled, estimated by the combined standard uncertainty of the measurement
σ_M^2	theoretical measurement variance of the population distribution being sampled
σ_{MR}	required measurement method standard deviation (upper limit)
σ_s	theoretical sampling standard deviation of the population distribution being sampled
σ_S^2	theoretical sampling variance of the population distribution being sampled
$\sigma(\bar{R}_I)$	standard deviation of the measured interference count rate
$\sigma\left(y\middle\vert Y=y_Q\right)$	variance of the estimator y given the true concentration Y equals y_Q
$\sigma(X_i, X_j)$	covariance for two input quantities, X_i and X_j

$S+$	Sign test statistic
$s(x)$	sample standard deviation of the input estimate, x_i
S_C	critical value of the net instrument signal
S_D	mean value of the net signal that gives a specified probability, $1-\beta$, of yielding an observed signal greater than its critical value S_C
s_i	minimum detectable number of net source counts in the observation interval (scanning)
$s_{i,surveyor}$	minimum detectable number of net source counts in the observation interval by a less than ideal surveyor (scanning)
Sr	strontium (isotope listed: ^{90}Sr)
Sv	seivert
Tc	techicium (isotopes listed: ^{99}Tc, ^{99m}Tc)
Th	thorium (isotopes listed: ^{228}Th: ^{230}Th, ^{232}Th, ^{234}Th)
Tl	thalium (isotopes listed: ^{201}Tl, ^{208}Tl)
t_B	count time for the background
t_S	count time for the source
U	expanded uncertainty
U	uranium (isotopes listed: ^{234}U, ^{235}U, ^{238}U)
$u(x_i)$	standard uncertainty of the input estimate, x_i
$u(x_i)/\lvert x_i \rvert$	relative standard uncertainty of x_i
$u(x_i,x_j)$	covariance of two input estimates, x_i and x_j
$u_c(y)$	combined standard uncertainty of y
$u_c(y)/y$	relative combined standard uncertainty of the output quantity for a particular measurement
$u_c^2(y)$	combined variance of y
$u_i(y)$	component of the combined standard uncertainty, $u_c(y)$, generated by the standard uncertainty of the input estimate x_i, $u(x_i)$, multiplied by the sensitivity coefficient, c_i
u_M	measurement method uncertainty
u_{MR}	required measurement method uncertainty
φ_{MR}	required relative measurement method uncertainty
$\phi_{\bar{A}}^2$	relative variance of the measured sensitivity
$\varphi(x_i)$	relative standard uncertainty of a nonzero input estimate, x_i, for a particular measurement. $\varphi(x_i) = u(x_i)/x_i$
$\Phi(z)$	cumulative normal distribution function
W_r	sum of the ranks of the (adjusted) reference measurements (WRS test)
W_s	sum of the ranks of the (adjusted) sample measurements (WRS test)
WS	weighted instrument sensitivity
x	estimate of the input quantity, X
X_i	an input quantity
x_C	the critical value of the response variable, x
x_Q	minimum quantifiable value of the response variable, x
y	year

y	estimate of the output quantity for a particular measurement, Y
Y	output quantity, measurand
y_C	critical value of the concentration
y_D	minimum detectable concentration (MDC)
y_Q	minimum quantifiable concentration (MQC)
yd	yard
yd^3	cubic yard
Z	atomic number
$z_{1-\alpha}$	$(1-\alpha)$-quantile of the standard normal distribution
$z_{1-\beta}$	$(1-\beta)$-quantile of the standard normal distribution
ZnS(Ag)	zinc sulfide (silver activated)

CONVERSION FACTORS

To Convert From	To	Multiply "From" Quantity By	To Convert From	To	Multiply By
acre	hectare	0.405	meter (m)	inch	39.4
	sq. meter (m^2)	4,050		mile	0.000621
	sq. feet (ft^2)	43,600	sq. meter (m^2)	acre	0.000247
becquerel (Bq)	curie (Ci)	2.7×10^{-11}		hectare	0.0001
	dps	1		sq. feet (ft^2)	10.8
	pCi	27		sq. mile	3.86×10^{-7}
Bq/kg	pCi/g	0.027	m^3	liter	1,000
Bq/m^2	dpm/100 cm^2	0.60	mrem	mSv	0.01
Bq/m^3	Bq/L	0.001	mrem/y	mSv/y	0.01
	pCi/L	0.027	mSv	mrem	100
centimeter (cm)	inch	0.394	mSv/y	mrem/y	100
Ci	Bq	3.70×10^{10}	ounce (oz)	liter (L)	0.0296
	pCi	1×10^{12}	pCi	Bq	0.037
dps	dpm	60		dpm	2.22
	pCi	27	pCi/g	Bq/kg	37
dpm	dps	0.0167	pCi/L	Bq/m^3	37
	pCi	0.451	rad	Gy	0.01
dpm/100 cm^2	Bq/m^2	1.67	rem	mrem	1,000
gray (Gy)	rad	100		mSv	10
hectare	acre	2.47		Sv	0.01
liter (L)	cm^3	1000	seivert (Sv)	mrem	100,000
	m^3	0.001		mSv	1,000
	ounce (fluid)	33.8		rem	100