

Hot Spot Limits—A Closer Look at Dose Modeling Used to Establish Hot Spot Release Criteria

Eric W. Abelquist (ORAU)
HPS Annual Meeting
Pittsburgh, PA
July 16, 2008

Acknowledgements

- Dr. Laurence Miller, my major professor
- My Dissertation Committee:
 - Dr. Lawrence Townsend
 - Dr. Ronald Pevey
 - Dr. Kevin Robinson
- Dr. Russell Zaretzki, Bayesian statistics help
- The help and support of my colleagues at the Department of Energy, Argonne National Laboratory and Oak Ridge Associated Universities

Need for Hot Spot Limits

- Following cleanup activities, the closure site is surveyed to demonstrate compliance with release criteria—average and hot spot limits
- Random sampling demonstrates that average contamination levels meet release criteria
- Scanning to identify hot spots have had mixed results—spotty contamination often remains following remediation
- Current approach used to generate the hot spot limits is **not** technically rigorous

How are Hot Spot Limits Currently Determined?

- NRC Regulatory Guide 1.86 provides a surface activity limit of 3 times the average guideline
- DOE 5400.5 provides a hot spot factor of $\text{SQRT}(100/A)$, where A is area of hot spot
- MARSSIM presents the most detailed approach for determining values for the DCGL_{EMC}



Objective of Hot Spot Research

- Determine hot spot limits by considering the best estimate of receptor dose from first principles
- Perform detailed look at how hot spots of various sizes actually deliver doses for specified environmental pathways

Radionuclides and Hot Spot Sizes Studied

- Radionuclides evaluated in this work: C-14, Co-60, Sr-90, Tc-99, I-129, Cs-137, Ra-226, Th-232, U-238, Pu-239, and Am-241
- Hot spot sizes considered: 10 m², 3 m², 1 m², 0.5 m², 0.1 m² and 0.01 m²
- 693 combinations of pathways, radionuclides and hot spot sizes evaluated
- Application to chemical contaminants

Results of Dose Modeling of Hot Spots

- Direct external radiation from contaminated soil
(hot spot sensitive)
- Inhalation exposure to resuspended soil
- Direct ingestion of soil
- Ingestion of drinking water from a groundwater source
(mildly hot spot sensitive)
- Ingestion of plant products grown in contaminated soil
- Ingestion of plant products irrigated with contaminated groundwater
- Ingestion of animal products grown onsite
- Ingestion of fish from a contaminated surface water source
(mildly hot spot sensitive)

Co-60 External Radiation Area Factors when Receptor Directly on Hot Spot

Hot Spot Area (m ²)	1000	10	3	1	0.5	0.1	0.01
MARSSIM AF	1	2.1	4.4	9.8	NA	NA	NA
RESRAD Dose (mrem/y)	7.3	3.2	1.5	0.65	0.65	0.65	0.65
RESRAD AF	1	2.27	4.82	11.3	11.3	11.3	11.3
MicroShield Dose (mrem/y)	4.7	2.1	1.0	0.41	0.22	4.7E-2	4.7E-3
MicroShield AF	1	2.30	4.73	11.4	21.3	100	990

Dissertation Results – External Radiation Pathway

- Is it reasonable to assume that receptor spends all allotted outdoor time on the hot spot?
- Area factor for a 10 m² hot spot is 2.3 when the receptor is located directly on the hot spot versus 79 when receptor 6 m away from hot spot
- Probabilistic approach (via Crystal Ball simulation) for assessing receptor distance from hot spot location

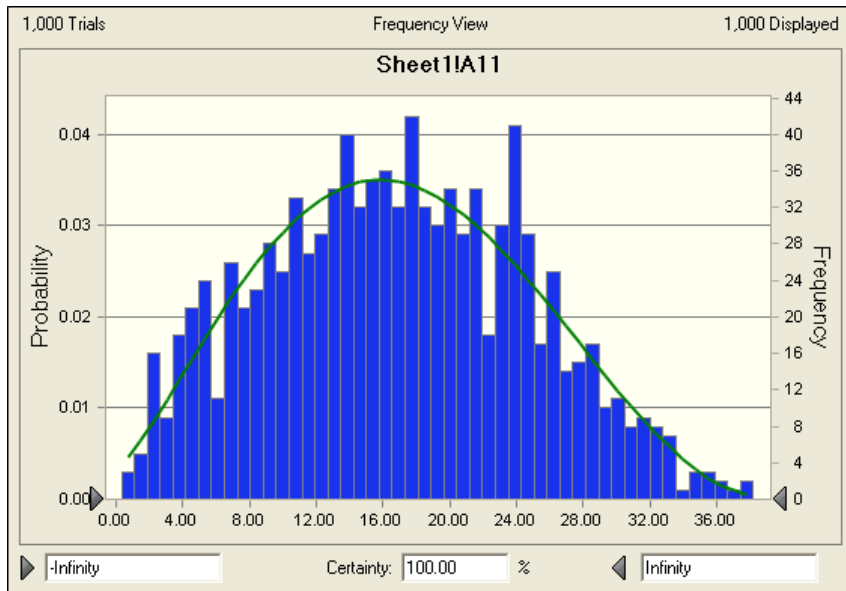
Simulation with Crystal Ball

- Receptor can be located at any location (x_1, y_1) within the survey unit, and the same goes for the hot spot (x_2, y_2) . The distance between the receptor and hot spot is given by:

$$l = \sqrt{(y_1 - y_2)^2 + (x_1 - x_2)^2}$$

- If Class 1 survey unit is 1000 m², then square dimensions are 31.6 m × 31.6 m
- Minimum distance is zero, and the maximum distance is the diagonal in the survey unit (44.7 m)

Simulation with Crystal Ball



Percentile Distance from Hot Spot (m)

0%	0.33
10%	6.01 (reasonably conservative)
20%	9.46
30%	12.28
40%	14.48
50%	16.64 (median distance from hot spot)
60%	18.78
70%	21.30
80%	24.01
90%	27.22
100%	38.19

Co-60 Area Factors for Soil when Receptor 6 m from Hot Spot

<u>Hot Spot Area (m²)</u>	<u>1000</u>	<u>10</u>	<u>3</u>	<u>1</u>	<u>0.5</u>	<u>0.1</u>	<u>0.01</u>
MicroShield Dose (mrem/y)	4.7	6.0E-2	1.9E-2	7.3E-3	4.1E-3	1.2E-3	1.6E-4
MicroShield AF	1	79.3	250	650	1150	4050	30,000

Co-60 Area Factors for Building Surfaces

Hot Spot Area (m ²)	100	3	1	0.5	0.1	0.01
RESRAD-BUILD Dose (mrem/y)	3.2E-5	6.1E-6	2.5E-6	1.4E-6	2.9E-7	2.9E-8
RESRAD-BUILD AF	1	5.19	12.6	23.6	111	1090
MicroShield Dose (mrem/y)	6.2E-5	1.2E-5	4.9E-6	2.6E-6	5.6E-7	5.7E-8
MicroShield AF	1	5.19	12.6	23.5	111	1100

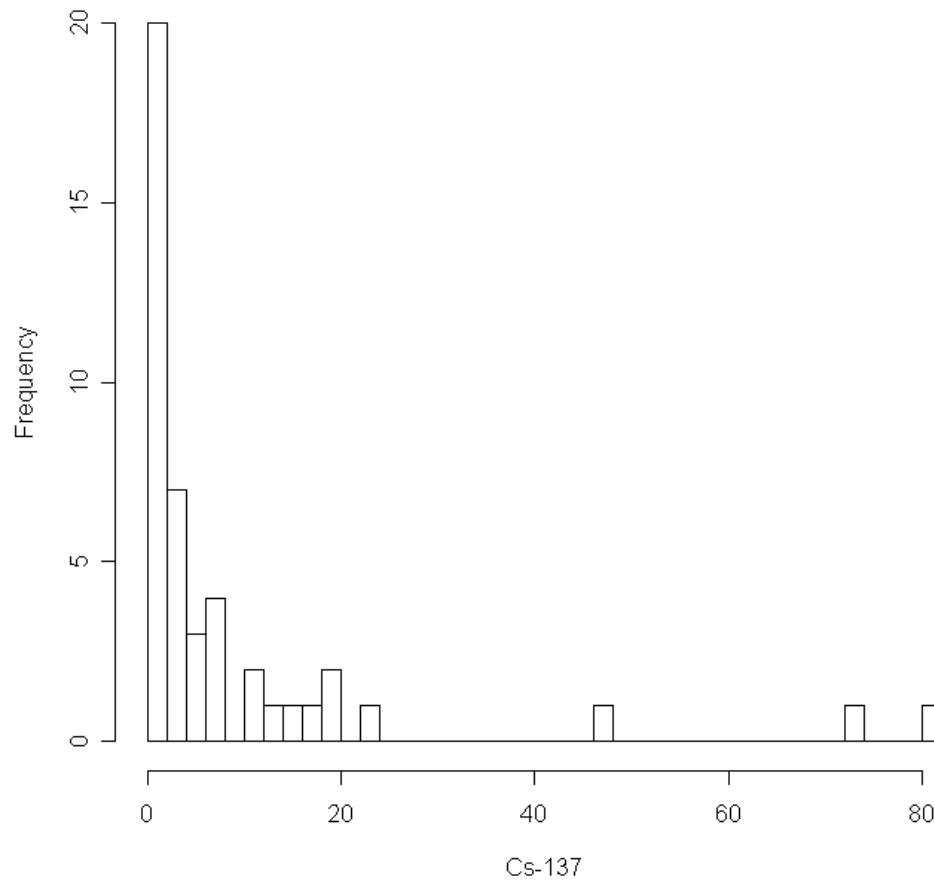
Note: DOE 5400.5 “area factor” for 0.01 m² (100 cm²) is 3

Statistical Hot Spot Assessment

- Consider an upper limit test on hot spots for assessing the acceptability of hot spots
- Demonstrate that the upper level hot spot distribution (e.g., 99th percentile) is below some upper limit
- Want to be able to describe the contaminant distribution in the survey unit—including the hot spots
- Approach provides a hot spot assessment that considers hot spots that may be present— but not found

Example: FSS with 45 Soil Samples of Cs-137

Histogram of y



Hot Spot Compliance Assessment

- Bayesian approach: Posterior distribution used to estimate the 99th percentile predicted to remain in the survey unit
- Compliance is demonstrated by comparing the predicted 99th percentile concentration with the $DCGL_{99th}$
- This approach also handles multiple hot spots, as the multiple hot spots are treated as part of the distribution



Recommendations

- Develop technically defensible approach for modeling the receptor dose due to hot spots
- Identify pathways and parameters that are particularly “hot spot sensitive”
- Perhaps establish hot spot limits based on the external radiation pathway alone
- Continue to apply ALARA principle to remediate hot spots when warranted