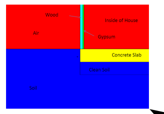
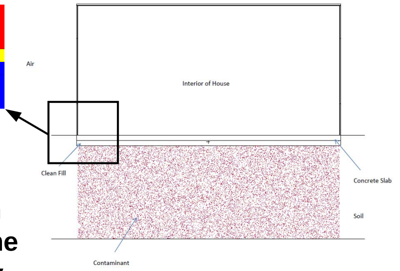
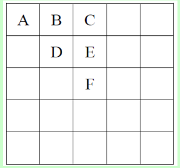
Development of Site-Specific Shielding Factors for Use in Radiological Risk Assessments

Cynthia Barr, Duane Schmidt, Sami Sherbini, U.S. Nuclear Regulatory Commission, Office of Federal and State Materials and Environmental Management Programs

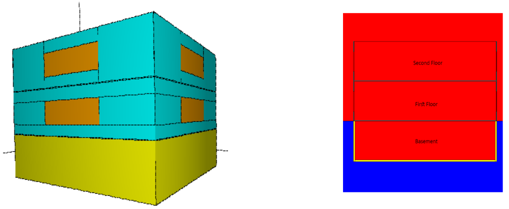



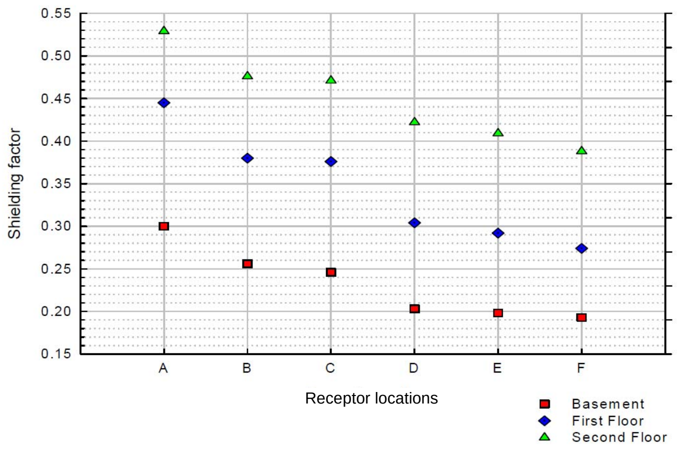
Slab with wood frame geometry



Receptor locations indoors (duplicated by symmetry)

Three-floor house with basement: geometry and shielding factor results





Shielding Factor (SF) and Indoor Dose

- A shielding factor (SF) is typically used to account for the attenuation of photons in building materials, leading to a reduction in dose to receptors while indoors (e.g., resident while indoors or office worker).
- SF = ratio of external gamma radiation level indoors to the level outdoors (so SF is a "transmission" factor).
- Shielding factors are typically not radionuclide- or energy-specific.
- In simplest form, indoor external gamma dose rate is proportional to SF: $D = C \times DCF \times T_{in} \times SF$

Why Develop Site-Specific Shielding Factors?

- For soil contaminated by gamma-emitting radionuclides, indoor external gamma radiation may be the most significant pathway.
- SF is one of the most risk-significant parameters, given relatively high indoor occupancy for resident receptors.
- Use of a bounding shielding factor in screening analyses leads to exceeding clean-up criteria.
- It is unclear whether radionuclide- or site-specific (e.g., based on building types) information would lead to higher or lower SF compared to central values of default parameter distributions.

Background and Details of Calculations

- Decommissioning site in northern Midwest, U.S.A.
- Future land use could be industrial or residential.
- Material is small particle size slag, relatively soil-like, mostly in top 1 m, but some to 2 m depth.
- Contaminants are Th-232, Th-230, and ingrown decay products. Th-232 series was used for conservatism (Th-230 decay product gamma energies are lower on average). Insignificant gamma energies were neglected.
- In the Midwest, house foundations are generally slab or basement, so these geometries were used for compliance for average member of critical group. Crawl space foundation was evaluated as bounding assessment. Different siding materials and impact of windows were considered.
- MCNP was used to calculate SF; geometries (esp. for basement) are too complex for MicroShield.
- SF varies with receptor location within a house, as well as reference point. Multiple locations were averaged to account for movement of the receptor within living space.

Conclusions/Recommendations/Lessons Learned

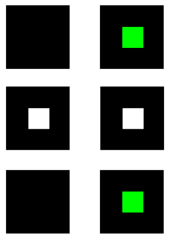
- Site-specific SFs are likely less than screening values. Use of default distribution is not always conservative; the analyst should evaluate applicability to geometry and radionuclides (γ energy).
- Heterogeneous or time-varying source may lead to spatially or temporally varying SFs (e.g., due to leaching or erosion).
- In-growth of radionuclides over time can lead to time-dependent shielding factors.
- Reference point must be consistent with dose modeling code (e.g., RESRAD assumes receptor is in the center of contaminated zone by default).
- Potentially important variables include: density of soil and materials; home construction types; material composition (e.g., soil); geometry of home; treatment of elevated areas; treatment of windows.

Uncertainty/Variability* in Shielding Factors (SF): Literature (RESRAD) Values

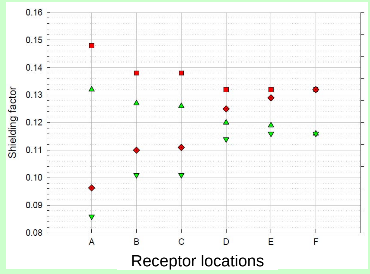
Geometry	SF
Brick house, slab or full basement	0.17
Frame house, slab or full basement	0.21
Frame house, crawl space	0.81
Frame house, partial basement	0.51

* for example, variability in house type and uncertainty in gamma energy

SF depends on shielding and geometry: two ways to model basement in RESRAD—MCNP reference geometry needs to match



Geometry and reference point affect SF results—local vs. center reference point



Example site-specific SF compared to potential default values

RESRAD deterministic	value	0.7
RESRAD default distribution	mean	0.31
	GM	0.27
Values calculated in present work	basement	0.36
	slab	0.37