Evaluation of Low-Tech Outdoor Remediation Methods Following Wide Area Radiological/Nuclear Incidents

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Radiological/Nuclear Incident Response

- Dirty bombs, nuclear explosions, and nuclear power plant accidents can contaminate vast urban and rural areas.
- Fukushima Nuclear Power Plant Accident contaminated an area the size of Connecticut, and the clean-up is still going on.
- If people can't get back to their homes and businesses in weeks-months, they may never return.
- What decontamination approaches would be used?
- How effective are they?

Urban Surface Decontamination

- Decontamination of urban building material surfaces using physical and chemical decontamination technologies


Decon testing using test stand at INL


EPA/DHS Wide Area Decon Demo – Battelle


Example RAD decon technology (DeconGel 1108)

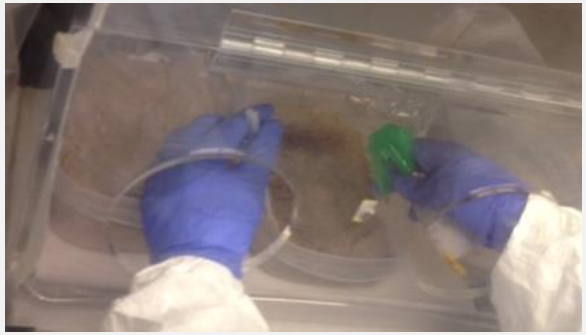

RAD decontamination testing of Wash Aid

Low-tech Remediation Methods

- Methods selected for availability and ease of use for personal residences, office buildings, and medical and first responder facilities
- Methods applied as they would be used by the public and workers cleaning building and facilities
- After Fukushima (and still today), Japanese public use various low tech methods

Technical Approach

- Radiologically tagged simulated fallout material (SFM)
  - Two particle sizes (<10 µm and >250 µm) allows studying efficacy as function of particle size
  - Similar to work done by EPA / Defense Research and Development Canada
  - Each size contaminated with different contaminant: rubidium-86 (<10 µm) and cesium-137 (>250 µm)
- Contamination method
  - Spike aqueous radionuclide into sized Arizona Road Dust, mix well, dry
  - Aqueous mist onto surfaces



Experimental Design

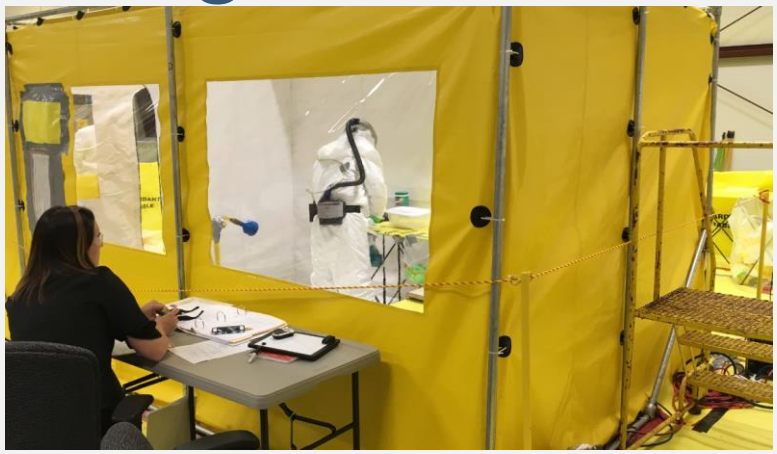
- Contaminate outdoor surfaces
  - Target activity of ≥ 2 µCi Cs-137 and 20 µCi Rb-86 (2 g of each particle size)
  - Light loading of 0.5 g AZ Road Dust
  - Aqueous mist on surfaces
- Measure pre-decontamination activities
  - 100 second measurements of contaminated samples to ensure detectability in shortest feasible time
  - 300 second (5 min) measurement of post-decon activity to measure removal in reasonable time

Application of particles and aqueous mist to surfaces

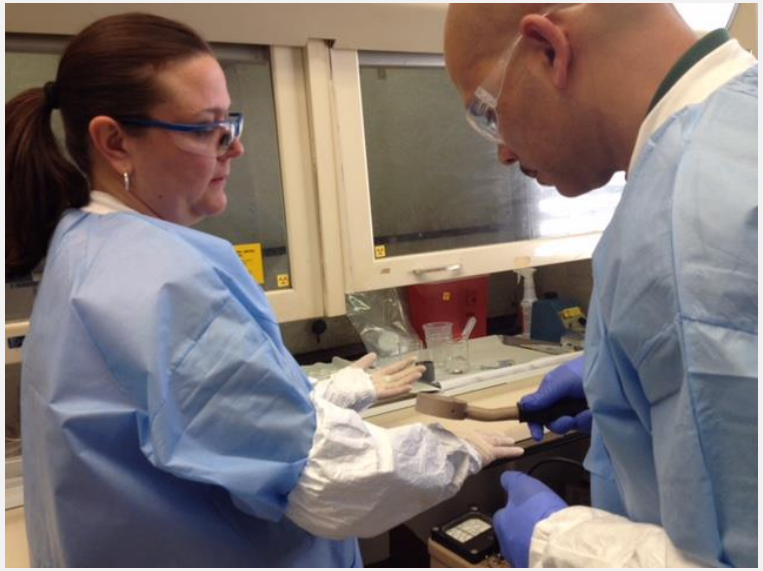
Activity measurement
Canberra InSpector 1000

Experimental Design

- Decon performed so surface covered twice with cleaning technologies
- All steps performed in containment tent
- HEPA filtration
- 100% HP oversight
- Air sampling for technician dose estimate
- Whole body surveys for technician contamination estimate

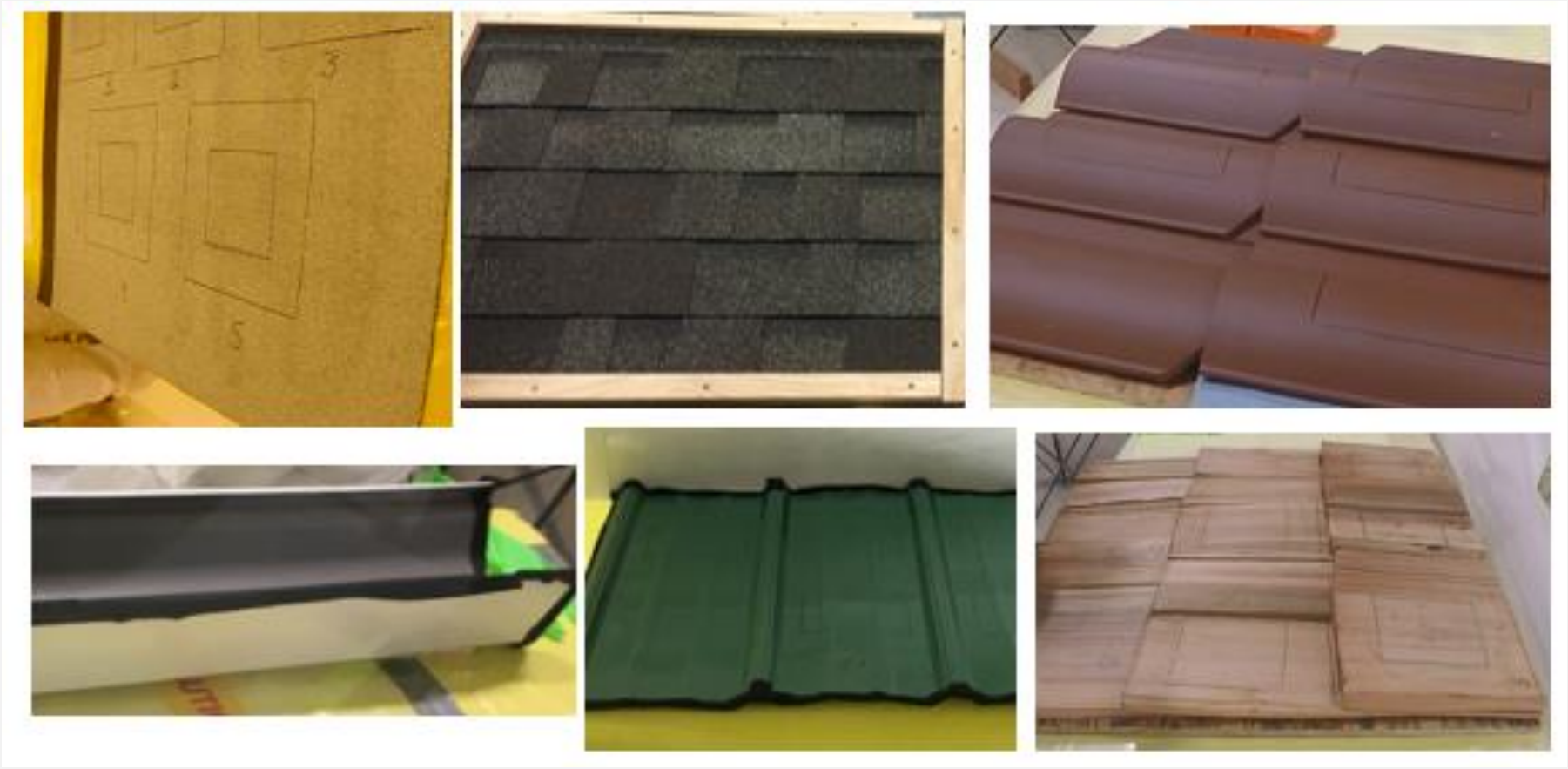


Containment Tent



Whole Body Surveys

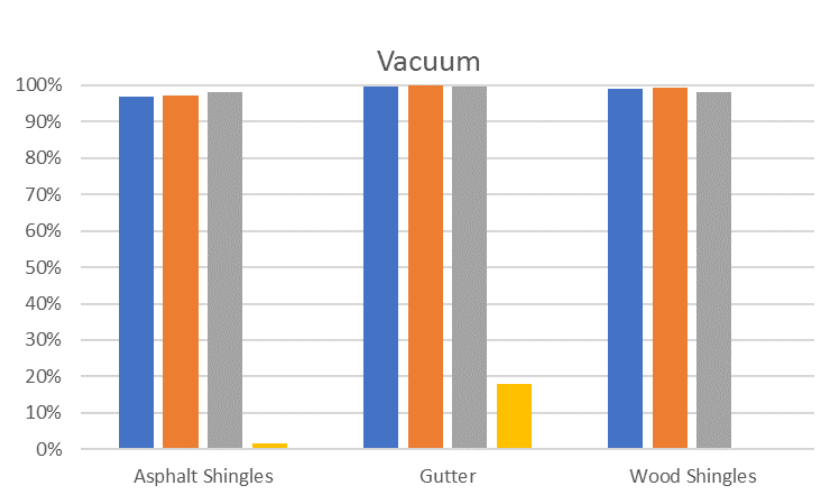
Roofing Surfaces

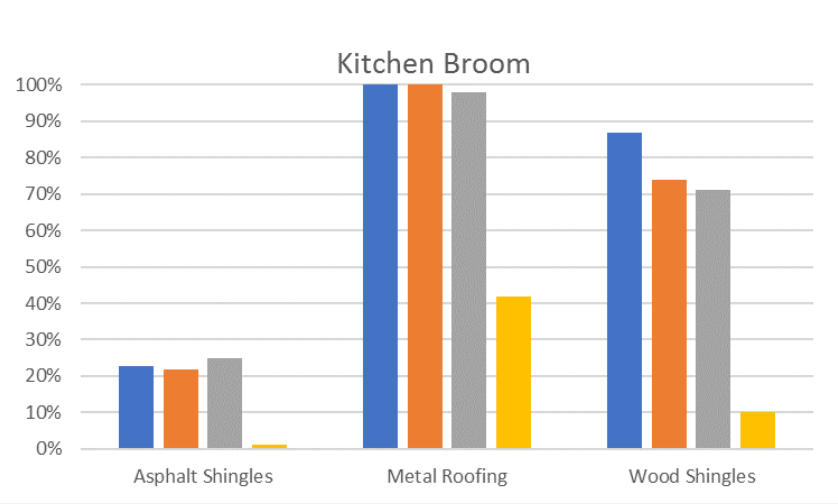


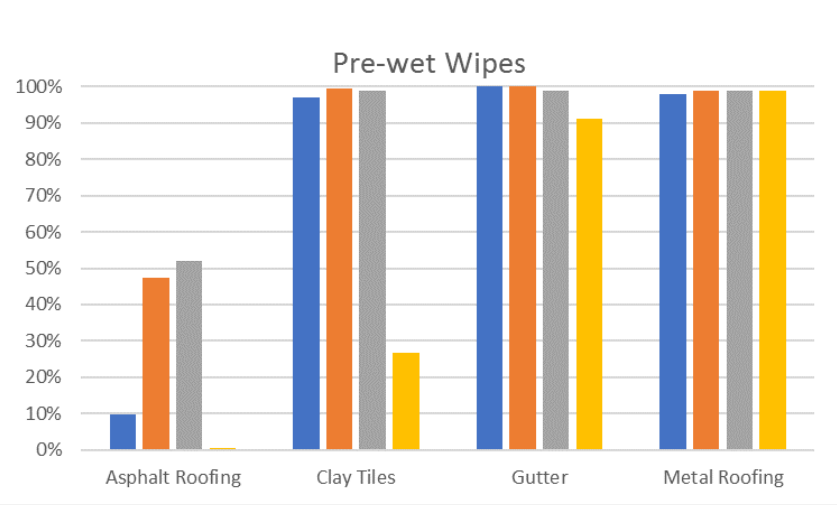
Roofing Surfaces Results

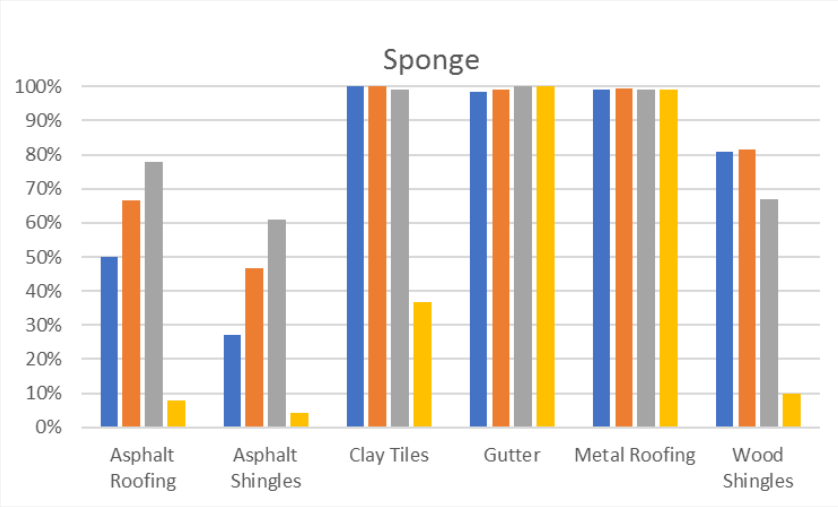
Method	Surface	% Removal for Each Contamination Deposition Approach			
		Cs-137, >250 µm Heavy Load SFM	Rb-86, <10 µm Heavy Load SFM	Cs-137, <10 µm Light Load SFM	Cs-137 ASFM
Vacuum	Asphalt Shingles	97 ± 0	97 ± 0	98 ± 1	2 ± 1
	Gutter	100 ± 0	100 ± 0	100 ± 0	18 ± 5
	Wood Shingles	99 ± 0	99 ± 1	98 ± 0	0 ± 2
Kitchen Broom	Asphalt Shingles	23 ± 6	22 ± 8	25 ± 3	1 ± 1
	Metal Roofing	>100 ± 1	100 ± 0	98 ± 1	42 ± 4
	Wood Shingles	87 ± 3	74 ± 4	71 ± 9	10 ± 16
Prewet Wipes	Asphalt Roofing	10 ± 5	47 ± 1	52 ± 8	0 ± 1
	Clay Tiles	97 ± 1	100 ± 1	99 ± 1	27 ± 3
	Gutter	100 ± 0	100 ± 0	99 ± 1	91 ± 1
	Metal Roofing	98 ± 1	99 ± 1	99 ± 0	99 ± 0
Push Broom	Asphalt Roofing	61 ± 5	75 ± 7	53 ± 17	3 ± 13
	Wood Shingles				1 ± 2
Wet Sponge	Asphalt Roofing	50 ± 5	67 ± 2	78 ± 3	8 ± 4
	Asphalt Shingles	27 ± 9	47 ± 8	61 ± 3	4 ± 1
	Clay Tiles	100 ± 0	100 ± 0	99 ± 0	37 ± 3
	Gutter	99 ± 1	99 ± 1	100 ± 2	100 ± 2
	Metal Roofing	99 ± 0	100 ± 0	99 ± 0	99 ± 1
	Wood Shingles	81 ± 4	81 ± 5	67 ± 17	10 ± 2

Roofing Surfaces Results









Roofing Observations

Heavy Loading SFM

- Efficacy mostly independent of particles size except for wood shingles (kitchen broom), asphalt roofing (prewet wipes and wet sponge), and asphalt shingles (wet sponge).
- 14 of 34 instances (across both particles sizes) the average %R were less than 90% and 6 of those instances the averages were less than 50%R
- 20 of 34 instances (across both particle sizes), the average %R was 95% or above
- Largest standard deviation was 9%
- Pre-wet wipes on the asphalt roofing - 10%R; Kitchen broom on the asphalt roofing was the next lowest average with 23%R for the large and small particles sizes, respectively

Light loading SFM

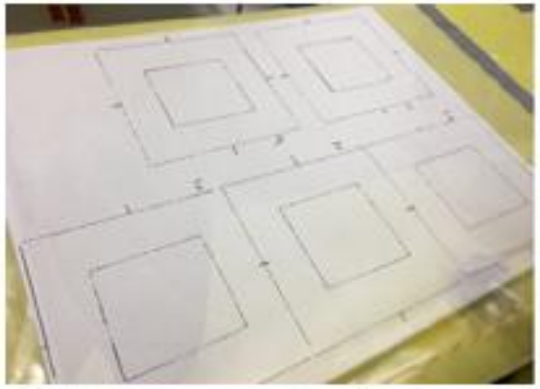
- 10 out of 17 average %R were 98% and above

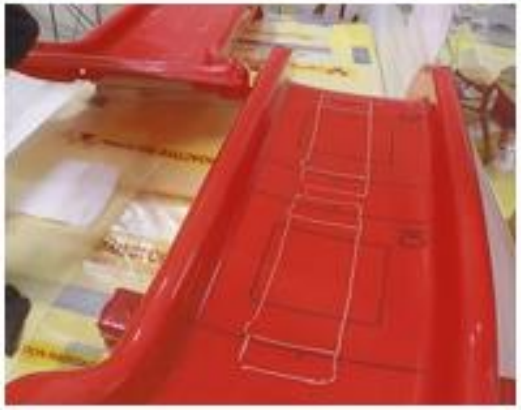
Aqueous SFM

- 4 of 18 instances had average %R exceeding 90%; no other exceeded 48%
- Several material/method combinations had little or no removal
- Prewet wipes and sponge on metal roofing and gutters had highest %R (91%-100%)

Siding and Other Surfaces



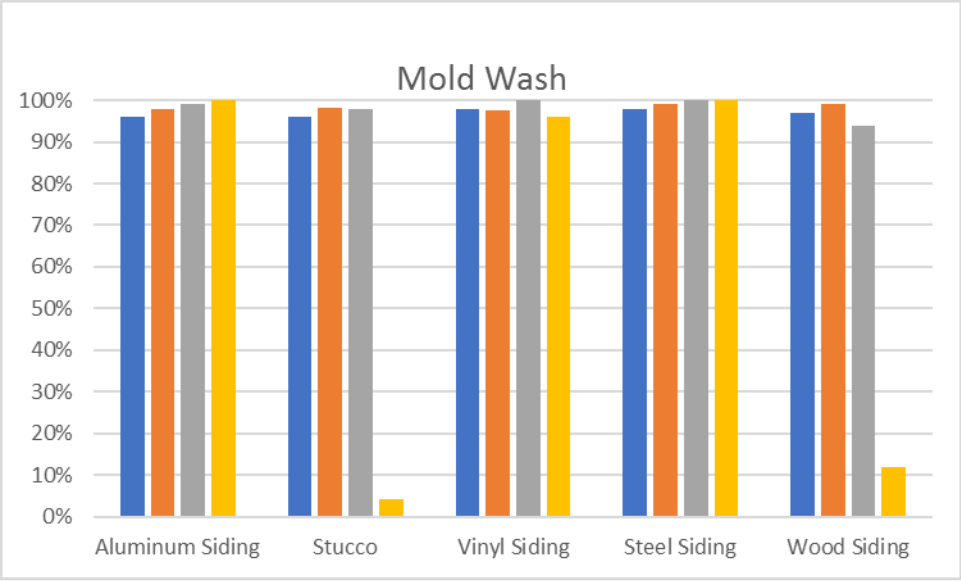


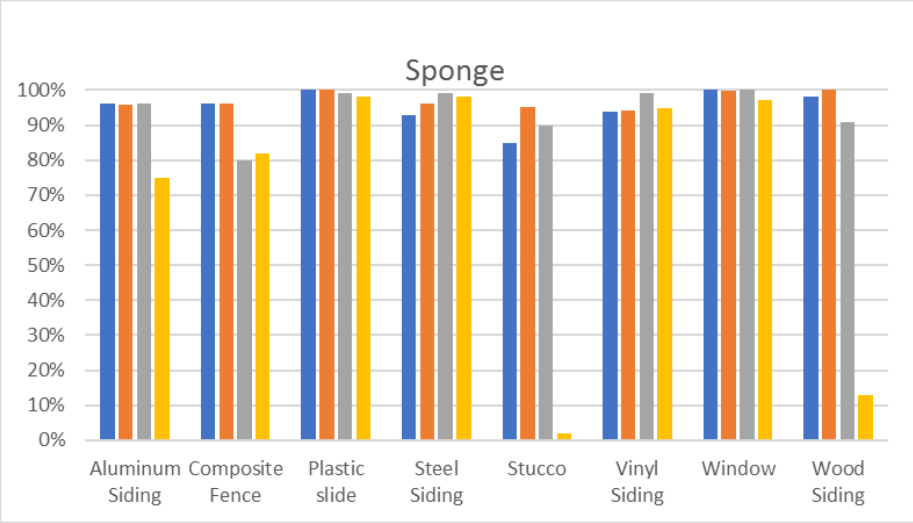


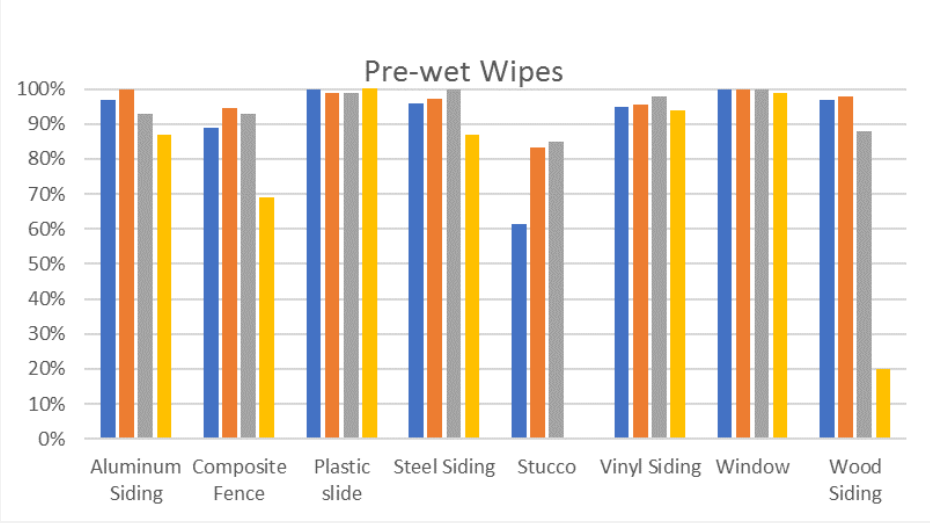
Siding and Other Surfaces Results

Method	Surface	% Removal for Each Contamination Deposition Approach			
		Cs-137 >250 µm Heavy Load SFM	Rb-86 < 10 µm Heavy Load SFM	Cs-137 < 10 µm Light Load SFM	Cs-137 ASFM
Mold Wash	Aluminum Siding	96 ± 3	98 ± 3	99 ± 1	>100
	Stucco	96 ± 2	98 ± 0	98 ± 1	4 ± 1
	Vinyl Siding	98 ± 1	98 ± 2	100 ± 0	6 ± 1
	Steel Siding	98 ± 1	99 ± 2	100 ± 0	100 ± 0
	Wood Siding	97 ± 1	99 ± 1	94 ± 0	12 ± 2
Prewet Wipes	Aluminum Siding	97 ± 1	100 ± 0	93 ± 3	87 ± 4
	Composite Fence	89 ± 3	95 ± 2	93[a] ± 4	69 ± 12
	Plastic slide	100 ± 0	99 ± 2	99 ± 0	>100
	Steel Siding	96 ± 3	97 ± 3	100 ± 1	87 ± 4
	Stucco	62 ± 17	83 ± 9	85 ± 3	0 ± 1
	Vinyl Siding	95 ± 3	95 ± 2	98 ± 0	94 ± 1
	Window	100 ± 0	100 ± 0	100 ± 0	99 ± 0
	Wood Siding	97 ± 0	98 ± 2	88 ± 3	20 ± 3
Sponge	Aluminum Siding	96 ± 3	96 ± 3	96 ± 2	75 ± 5
	Composite Fence	96 ± 1	96 ± 2	80 ± 4	82 ± 3
	Plastic slide	100 ± 0	100 ± 0	99 ± 0	98 ± 1
	Steel Siding	93 ± 2	96 ± 2	99 ± 0	98 ± 0
	Stucco	85 ± 4	95 ± 1	90 ± 0	2 ± 1
	Vinyl Siding	94 ± 4	94 ± 6	99 ± 0	95 ± 1
	Window	100 ± 0	100 ± 0	100 ± 0	97 ± 1
	Wood Siding	98 ± 0	100 ± 1	91 ± 2	13 ± 3
Squeegee	Window	99 ± 0	100 ± 1	100 ± 0	96 ± 2

Siding and Other Surfaces Results







Siding and Other Surfaces Observations

Heavy Loading SFM

- Efficacy mostly independent of particles size
- 38 of 42 instances (across both particles sizes) the average %R was 94% or greater
- 16 of 42 instances, the average %R plus or minus the standard deviation included 100%
- Largest standard deviation was 17% and 9% for prewet wipes on stucco, no other standard deviation was greater than 6%
- Prewet wipes on stucco provided the lowest average %R, 62% and 83% for the large and small particles sizes (less precise results)

Light loading SFM

- 15 out of 21 were 93% or above, lowest %R was 80% composite fence with wet sponge

Aqueous Contaminant Application

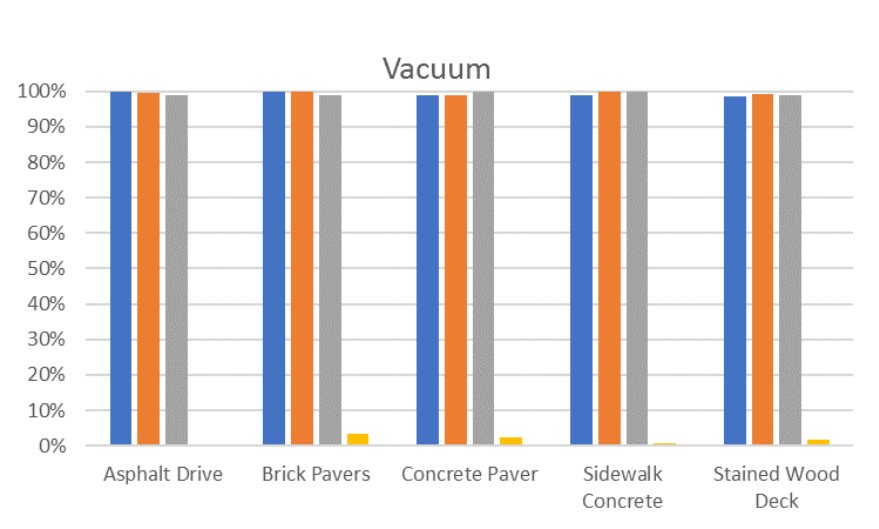
- 10 of 21 instances had average %R exceeding 90%
- 6 instances, the average %R did not exceed 20%
- Stucco had no greater than 4% R
- Mold wash/aluminum and steel siding, prewet wipes/plastic slide, and squeegee/window had %Rs of 100%.
- For the three non-porous sidings (vinyl, steel, and aluminum), the mold wash exhibited removals greater than 96%

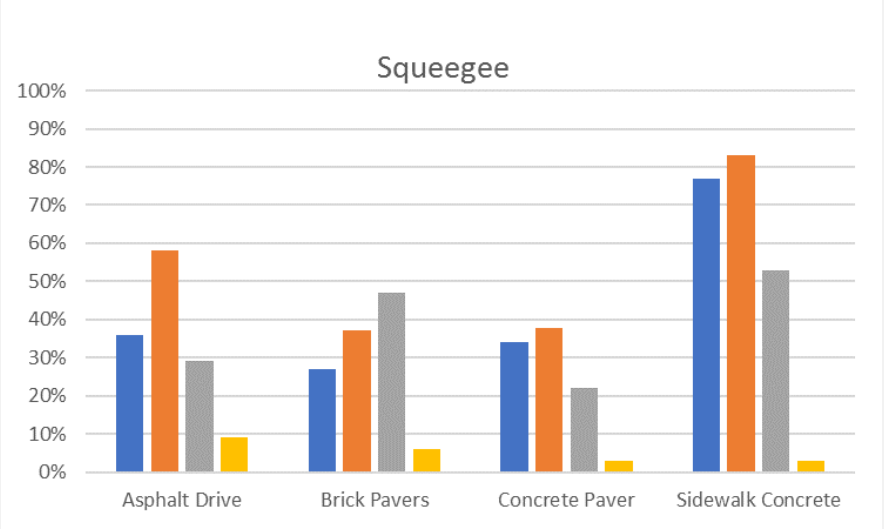
Hardscapes

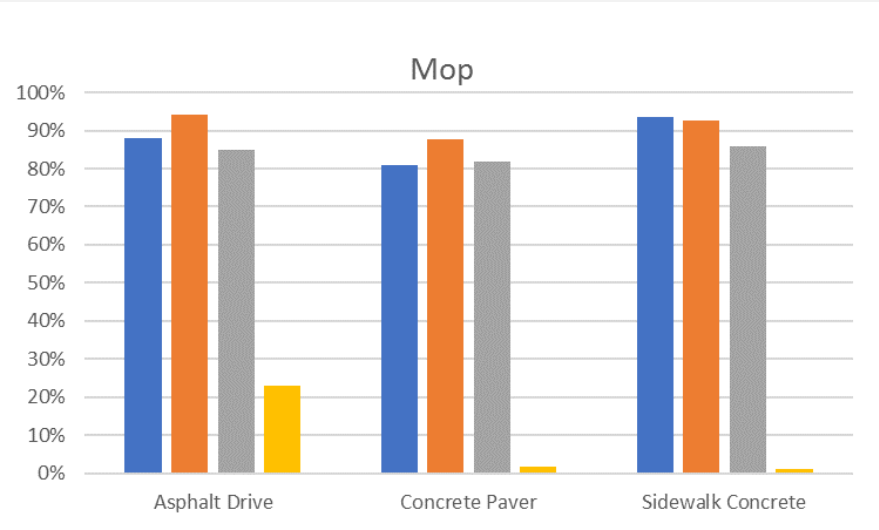
Hardscape Results

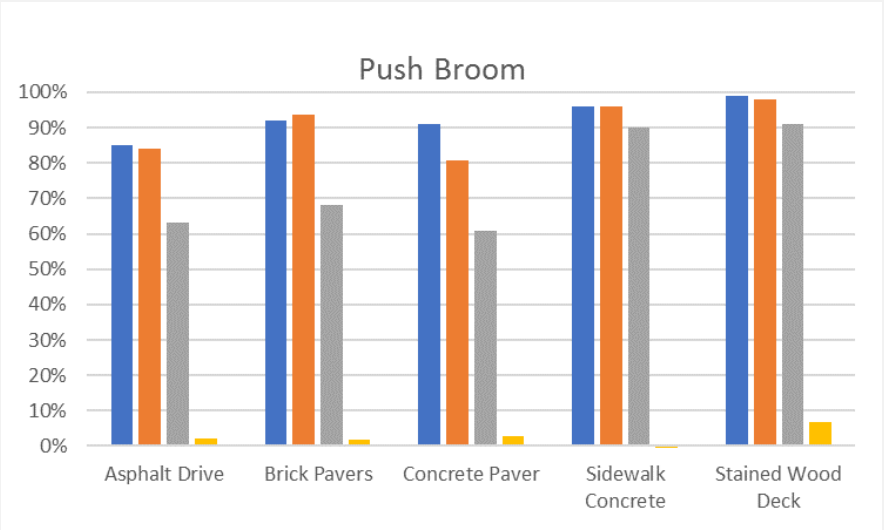
Method	Surface	% Removal for Each Contamination Deposition Approach			
		Cs-137 >250 µm Heavy Load SFM	Rb-86 < 10 µm Heavy Load SFM	Cs-137 < 10 µm Light Load SFM	Cs-137 ASFM
Deck Wash	Stained Wood Deck	99 ± 0	100 ± 1	99 ± 1	47 ± 12
Vacuum	Asphalt Drive	100 ± 0	100 ± 1	99 ± 1	0 ± 2
	Brick Pavers	100 ± 0	100 ± 0	99 ± 0	4 ± 1
	Concrete Paver	99 ± 0	99 ± 1	100 ± 1	2 ± 1
	Sidewalk Concrete	99 ± 0	100 ± 0	100 ± 0	1 ± 2
	Stained Wood Deck	99 ± 0	99 ± 1	99 ± 0	2 ± 1
Squeegee	Asphalt Drive	36 ± 13	58 ± 7	29 ± 8	9 ± 3
	Brick Pavers	27 ± 7	37 ± 6	47 ± 4	6 ± 1
	Concrete Paver	34 ± 5	38 ± 5	22 ± 4	3 ± 2
	Sidewalk Concrete	77[a] ± 2	83[a] ± 3	53 ± 6	3 ± 0
Mop	Asphalt Drive	88 ± 9	94 ± 5	85 ± 5	23 ± 1
	Brick Paver	91 ± 4	95 ± 3	89 ± 2	12 ± 2
	Concrete Paver	81 ± 5	88 ± 3	82[b] ± 6	2 ± 1
	Sidewalk Concrete	94 ± 1	93 ± 3	86 ± 2	1 ± 1
Push Broom	Asphalt Drive	85 ± 7	84 ± 6	63 ± 18	2 ± 3
	Brick Pavers	92 ± 4	94 ± 2	68 ± 16	2 ± 3
	Concrete Paver	91 ± 0	81 ± 3	61 ± 7	3 ± 2
	Sidewalk Concrete	96 ± 1	96 ± 1	90 ± 4	-1 ± 2
	Stained Wood Deck	99 ± 0	98 ± 1	91 ± 3	7 ± 4
Pump Sprayer	Concrete Paver	88 ± 4	54 ± 4		3 ± 4
	Brick Pavers	92 ± 4	87 ± 3		-5 ± 5
	Stained Wood Deck	98 ± 0	98 ± 1		49 ± 3
	Sidewalk concrete	97 ± 2	94 ± 3		5 ± 3

Hardscape Results









Hardscape Observations

Heavy Loading SFM

- Efficacy mostly independent of particles size
- Vacuum removed all particles with %Rs of 99% or 100%.
- Only 3 of 8 squeegee particle removal scenarios resulted in %Rs of greater than 50%
- 3 of 6 mop particle removal scenarios resulted in %Rs greater than 90%, the rest ranged from 81% to 86%
- Push broom removed heavy load of mixed sized particles better than the lighter load of small particles

Light loading SFM

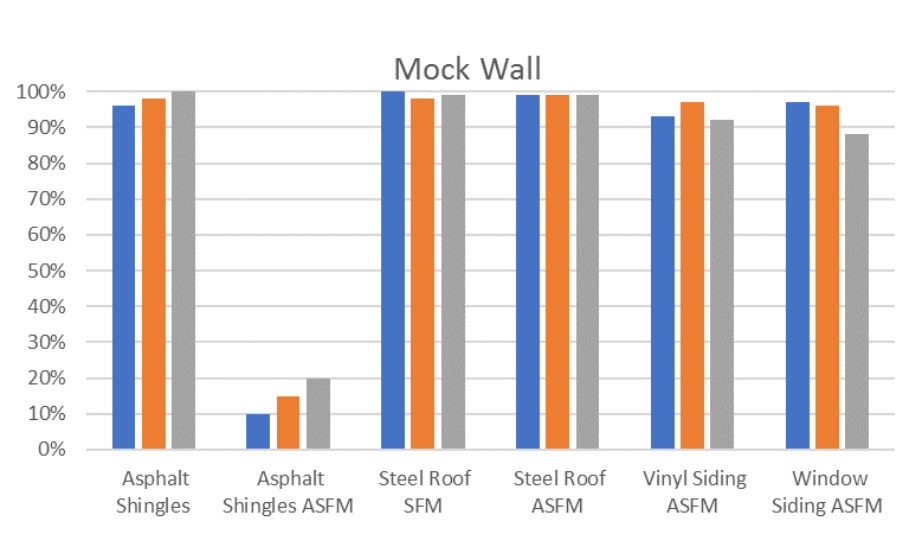
- Except for the push broom remediation, the light loading was removed at similar magnitudes as the heavy loaded particles

Aqueous Contaminant Application

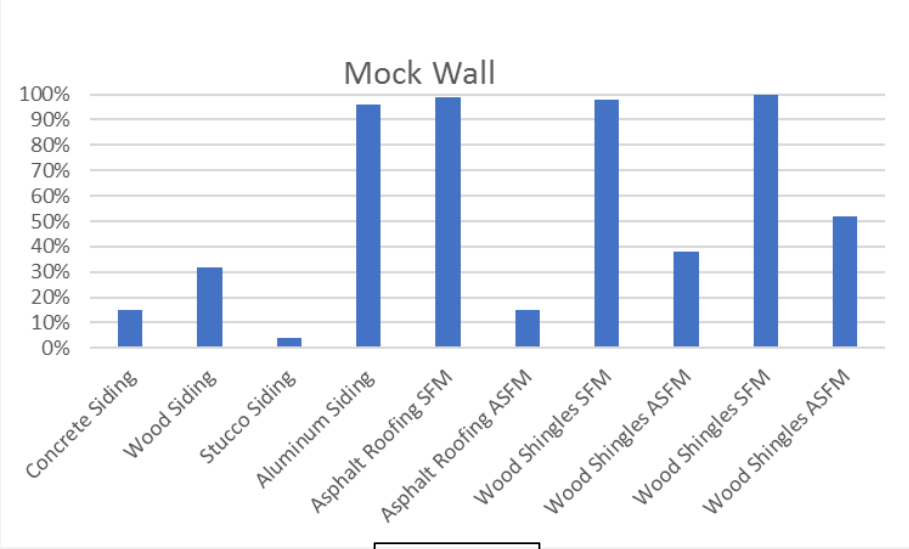
- 18 of 21 instances had average %R below 10%

Mock Wall

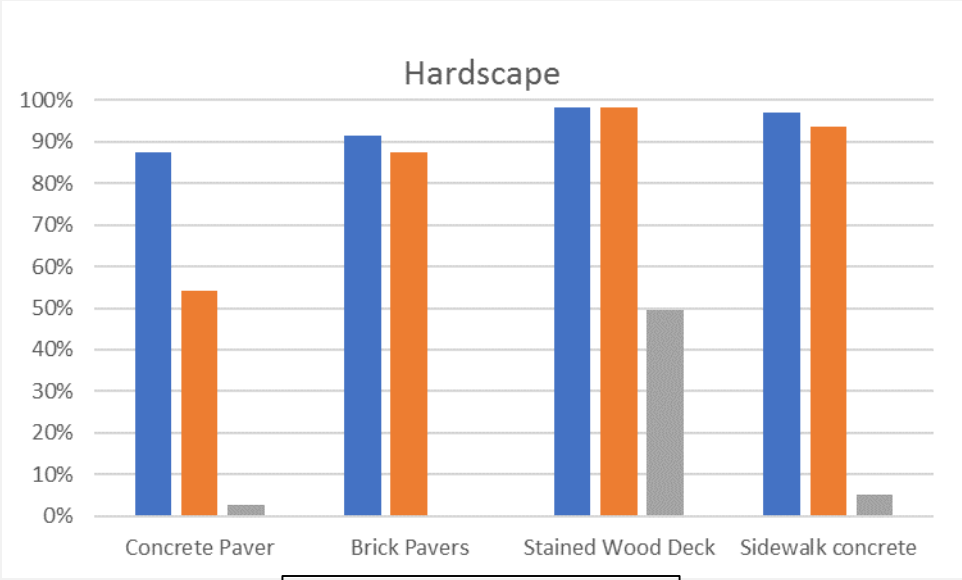
Pump Sprayer Results



Cone, fan, and stream spray



Fan spray



Fan spray – SFM and ASFM

Pump Sprayer Observations

- Sprayer removed all particles with %Rs of greater than 96%
- ASFM removal widely variable depending on surface
- Vinyl siding and window removed greater than 96% for fan setting, other two settings are more variable
- Stucco, wood, and concrete siding range from 4%R to 32%R, for fan setting
- Average volume used per surface was 1 L and the average spray flow was 0.5 L/min
- For hardscapes, sprayer resulted in %Rs from 87% to 98% smaller particles on the concrete pavers which were only removed at 54%

“Typical” 1,900 ft² Home for Waste Estimates

Waste Stream Estimates

Surface	Amount	Method	Number of items	Potential %R
Asphalt shingles and gutter	160 m^2	Vacuum	1 vacuum with 20 mg/cm^2 SFM	97%
Vinyl siding	150 m^2	Mold wash	857 terry towels with 20 mg/cm^2 SFM	100%
Windows	10 m^2	Pre-wet wipes	286 wipes with 20 mg/cm^2 SFM	100%
Sidewalk Concrete	80 m^2	Vacuum	1 vacuum with 20 mg/cm^2 SFM	99%
Stained wood deck	13 m^2	Vacuum	1 vacuum with 20 mg/cm^2 SFM	99%

Surface	Estimated Waste Volume		
	Heavy SFM Loading	Light SFM Loading	ASFM
Asphalt shingles and gutter	1 vacuum (6 kg), 32 kg SFM	1 vacuum (6 kg), 3 kg SFM	16 kg sponges, 40 kg mold wash in sponges
Vinyl siding	51 kg terry towels and 40 kg of mold wash saturated in towels, 30 kg SFM	39 kg terry towels and 31 kg of mold wash saturated in towels, 3 kg SFM	220 L rinse water
Windows	1 kg in wipes; 2 kg SFM	0.5 kg in wipes; 200 g SFM	0.5 kg in wipes
Sidewalk Concrete	1 vacuum (6 kg), 16 kg SFM	1 vacuum (6 kg), 2 kg SFM	120 L rinse water
Stained wood deck	1 vacuum (6 kg), 3 kg SFM	1 vacuum (6 kg), 300 g SFM	20 L rinse water
Estimate of total mass, volume, and activity	181 kg into ten 0.2 m^3 bags- (only 1 vacuum disposed) If initial fallout had activity of 0.5 µCi/g, then 91 mCi.	85 kg into five 0.2 m^3 bags – 1 vacuum disposed If initial fallout had activity of 0.5 µCi/g, then 43 mCi	56 kg into three 0.2 m^3 bags; 360 L of liquid in 2 waste drums If initial activity of 0.01 mCi/m^2, then 4 mCi

Research Opportunities

- Efficacy of salt solution remediation technologies
- Decontamination worker safety assessment
- Domestic “track-in” experiments
- Fallout intrusion into ventilation, windows, etc.

Additional Questions?

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