Wash Penalty Factors: Insight into the effects of water wash down of building materials for RN decontamination

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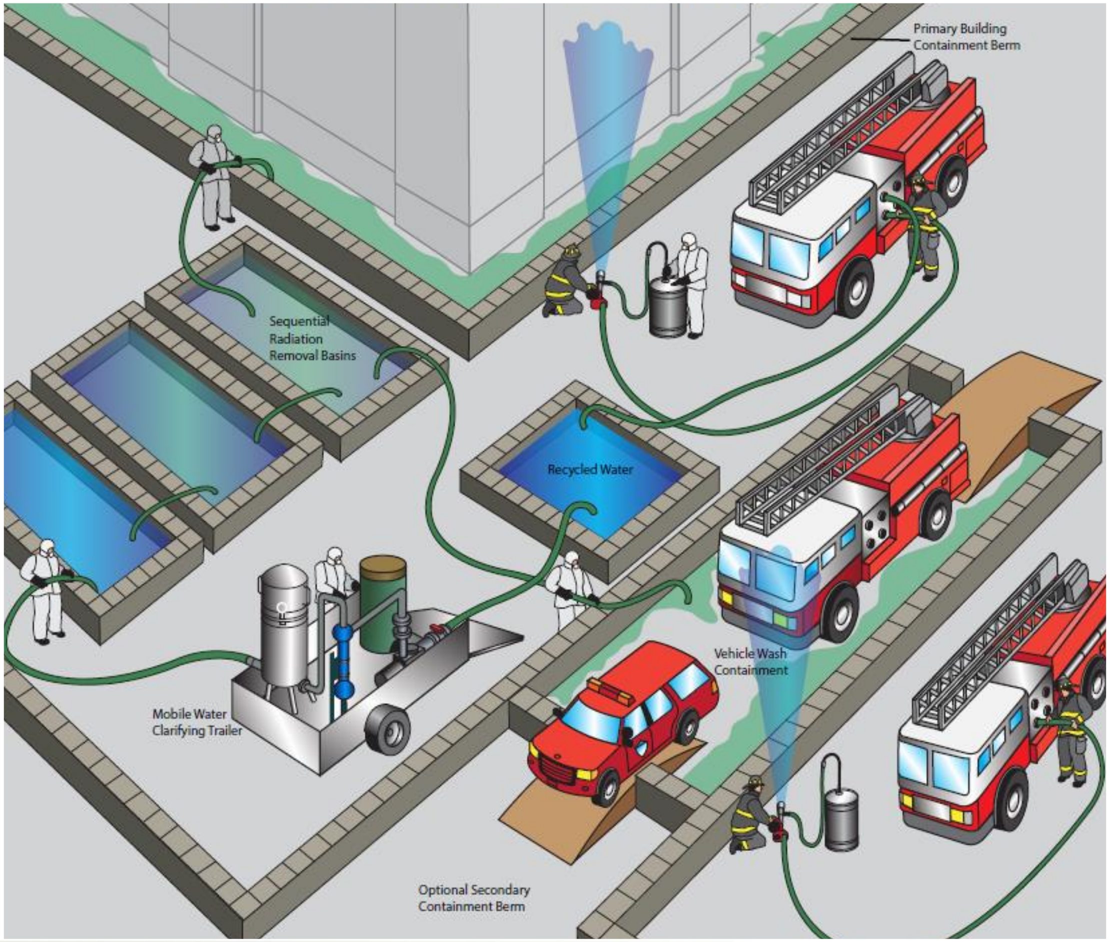
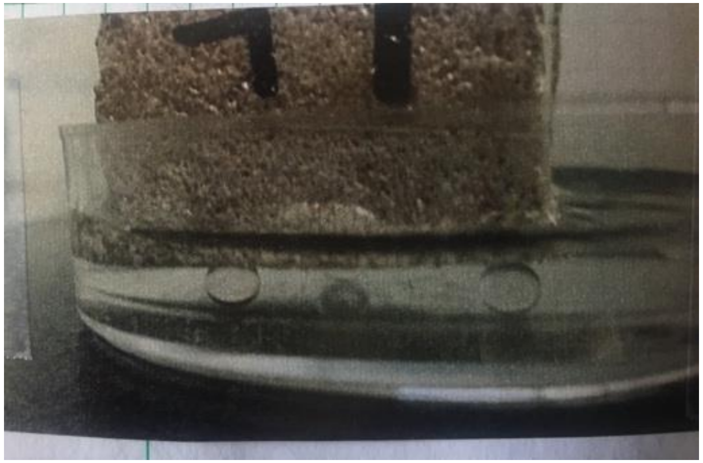
IWATERS

- In partnership with the USEPA, DOD, and DHS
- Integrated Wash-Aid, Treatment, and Emergency Reuse System (IWATERS) is designed for soluble and particulate radioactive contaminants.
- Components of the technology are:
  - Worker-friendly wash aid additives to tap water
  - Capture and containment of the contaminated runoff
  - Use of common sequestering agents to remove the dissolved radionuclides from the wash water
  - Filtration and reuse of the wash water for continued operations

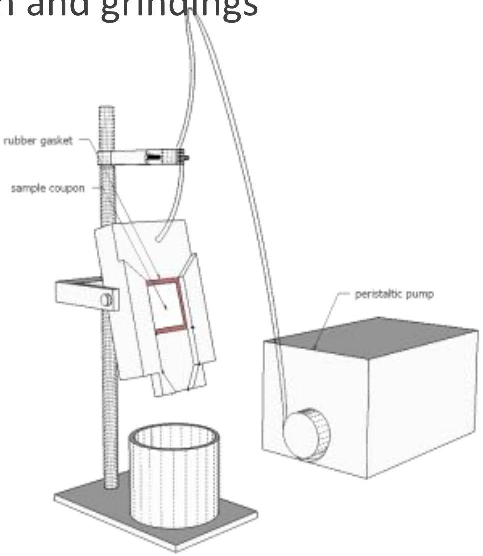


Test scheme

- ^{137}Cs, ^{85}Sr, and ^{152}Eu deposited onto a number of common building materials
- Decontamination based on K^+ salt at varying concentrations
  - Static bath test
  - Low pressure water flow
- Measure the decontamination efficacy
- Measure depth profile for residual contamination
  - Sand the surface and weigh and measure the coupon and grindings



Static test with concrete coupon suspended in wash solution



Schematic of flow system. A wash solution is pumped over the coupon and into a beaker.

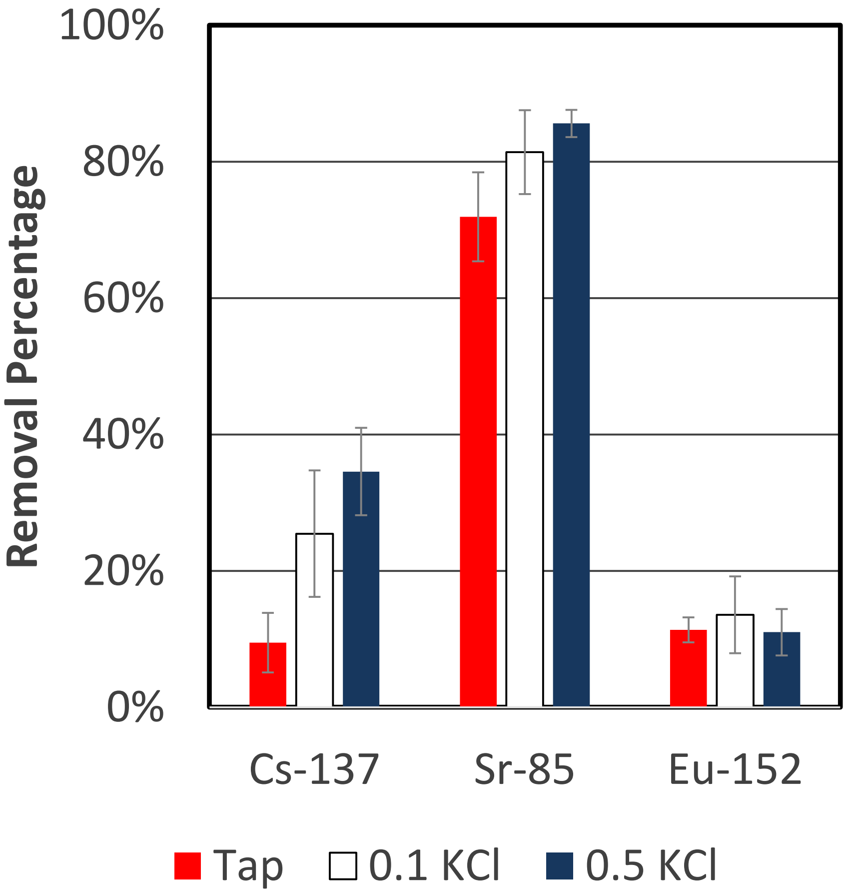
Methods

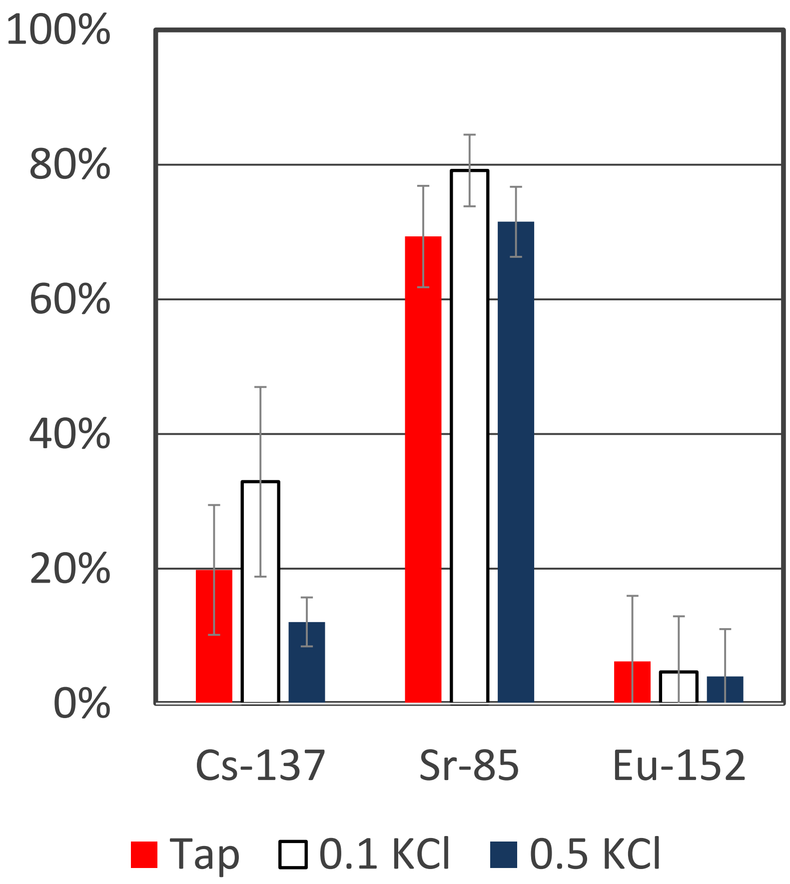
- Coupons were placed in a climate control chamber for a minimum of three days at 70% humidity and 22-23°C.
- 100 µL of ^{152}Eu, ^{137}Cs, and ^{85}Sr in near equal activity [~0.045 µCi per radionuclide or 5000 counts per minute (cpm)]
  - Coupons were allowed to dry for approximately 15-20 minutes for the porous and 45-60 min for the non-porous materials, wrapped in plastic wrap, placed inside of a plastic bag
  - Radiometrically counted for the specific gamma-ray photopeaks (^{152}Eu = 121 and 344 keV, ^{85}Sr = 514 keV, and ^{137}Cs = 662 keV) for 10 minutes at the face of the detector (HPGe, ORTEC Detective DX-100T).
  - Quality control checks were done on the detector to determine the ideal placement of the coupon to minimize variability
  - After counting, coupons were unwrapped and placed in the climate control chamber for 14-18 hours before testing.
  - In this manner, the contamination on each coupon was aged 15-20 hrs before being decontaminated.

Test coupon materials

STATIC TESTS FLOW TESTS

Asphalt

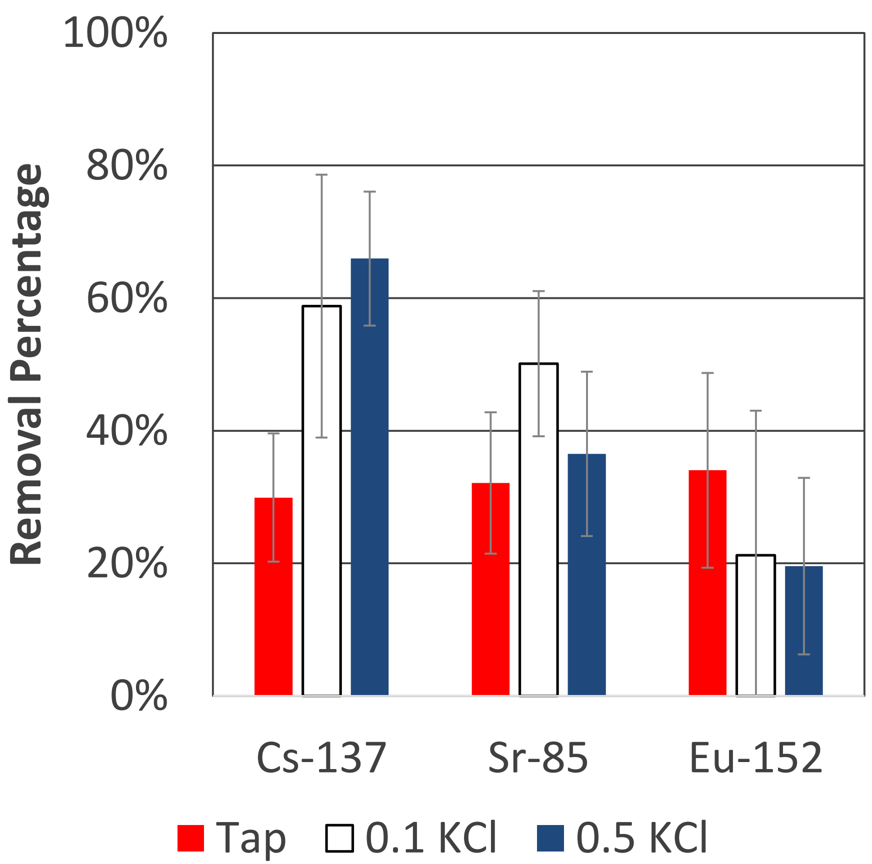


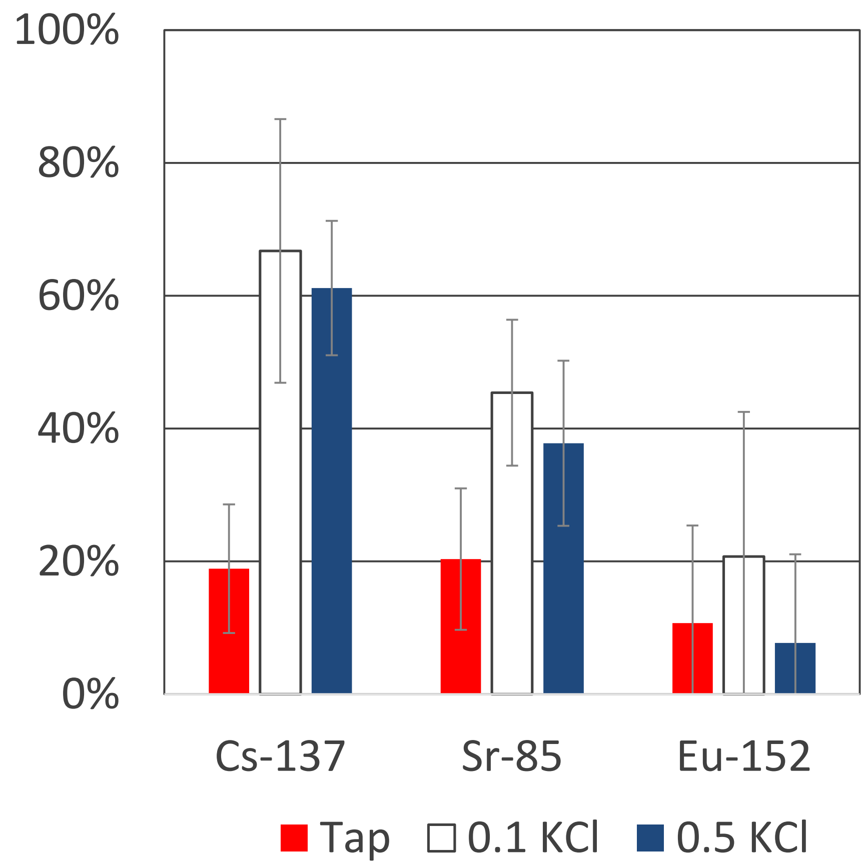


[KMD1]

STATIC TESTS FLOW TESTS

Concrete

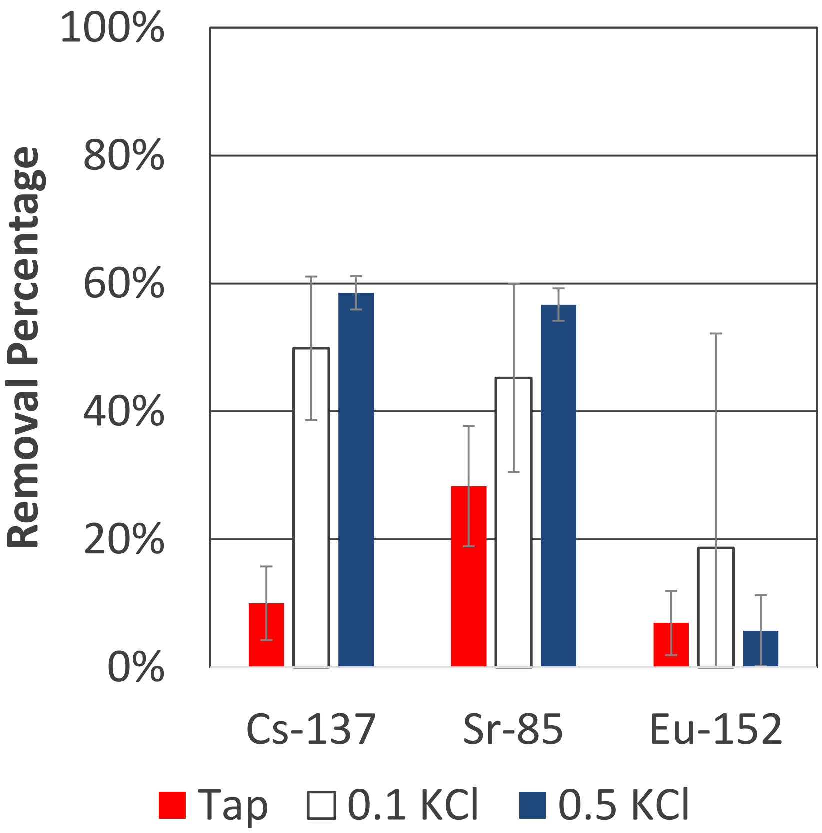


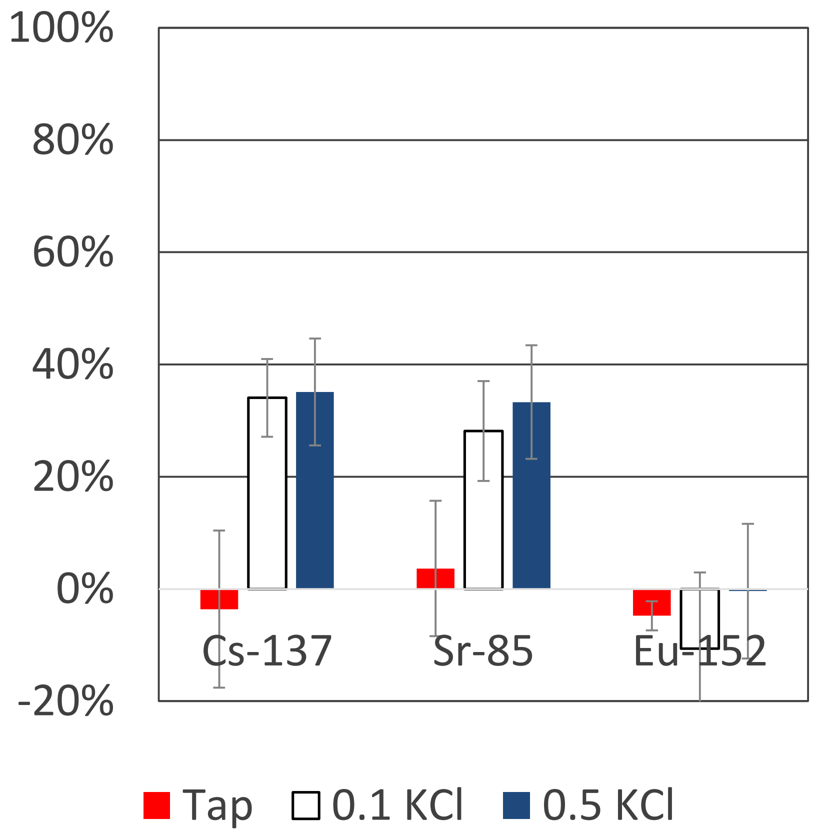


STATIC TESTS

FLOW TESTS

Brick





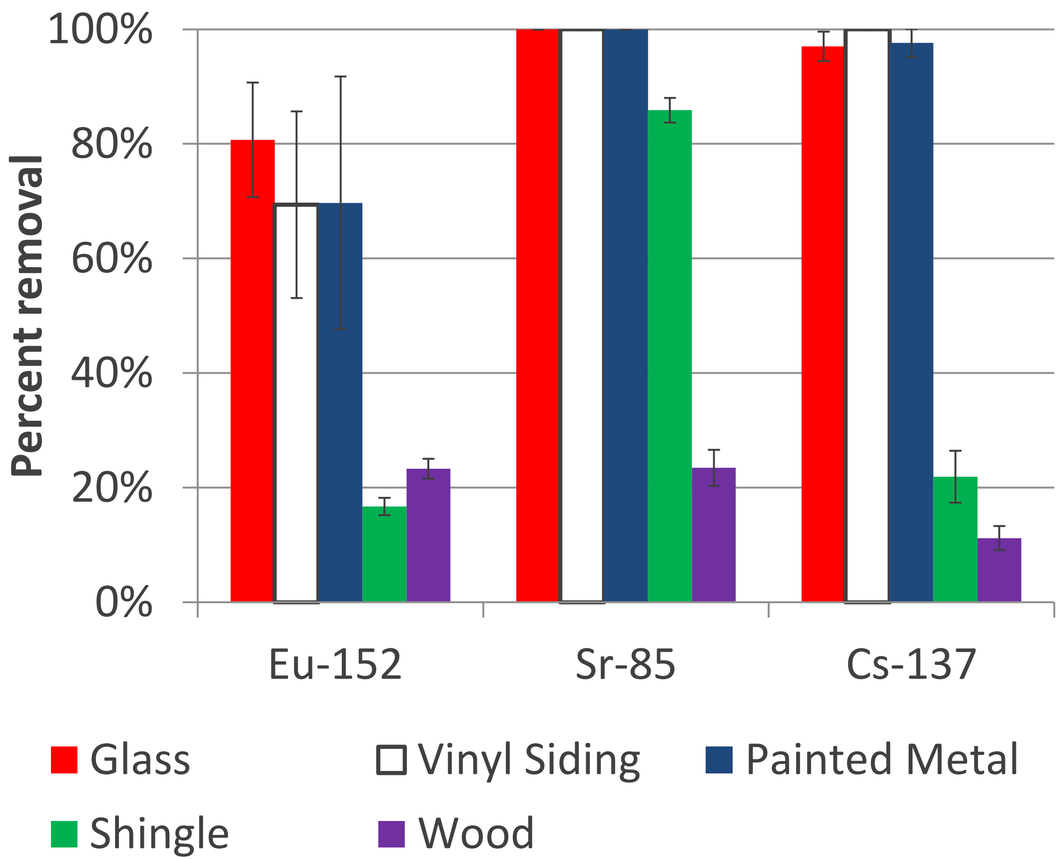
Effect of Seawater as Decontaminant

- No significant differences between the static and flow test results and also with our tests with K^+.
- Sandalls-1987 showed that Na^+ and other ions such as Ca^{2+} are significantly less effective than NH_4^+ in desorbing Cs^+ from sorption sites on all the materials they tested.
  - Sandalls' materials were regionally sourced in the UK
  - Moreover, it may suggest the need for tests in practical time-scales to inform emergency or early phase response periods
    - Sandalls' equilibration times were reported as 12 hrs soak contamination and 48 hr soak decontamination.

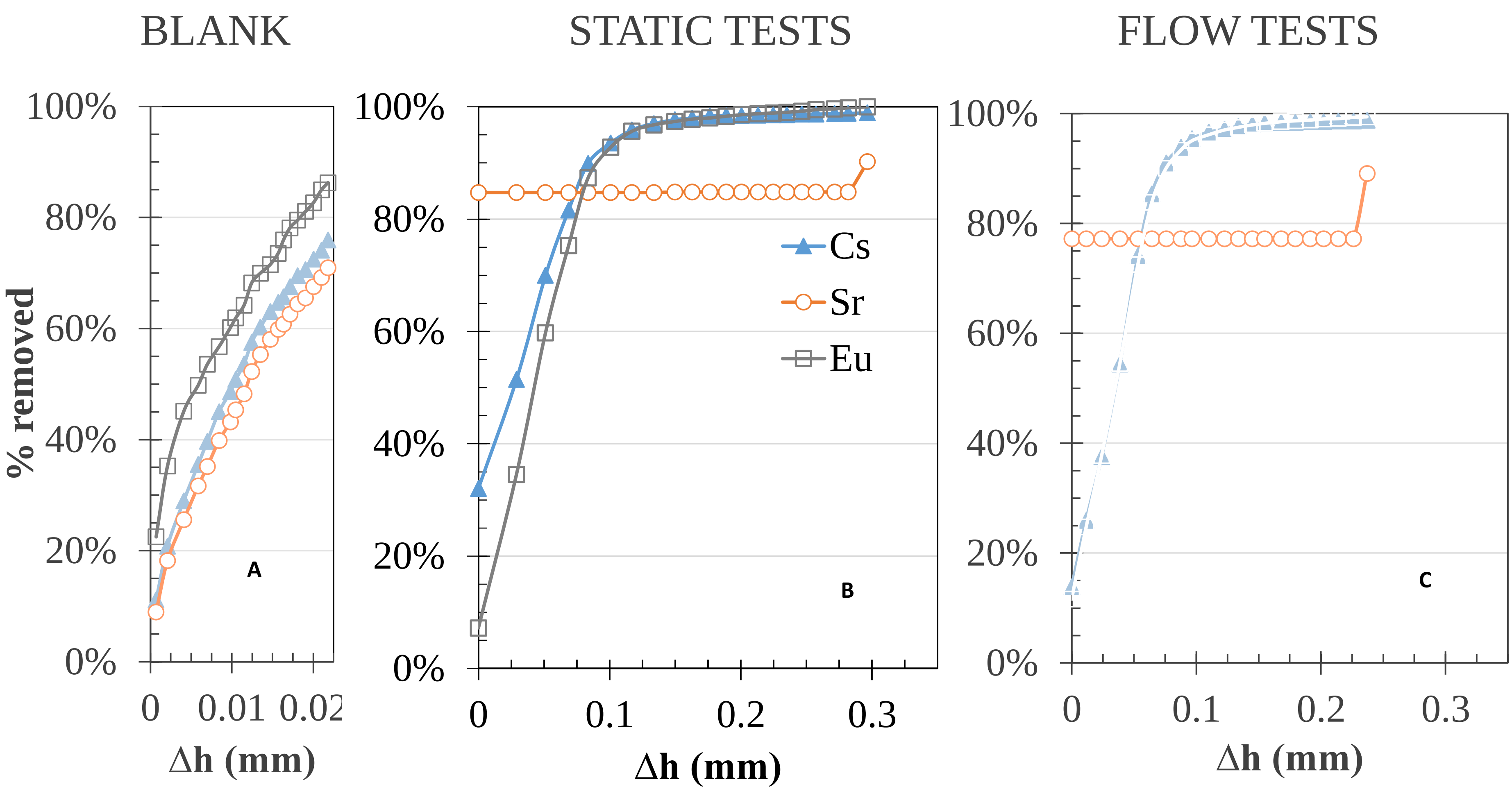
		Static	Flow
Asphalt	^{137}Cs	49±11%	58±8%
	^{85}Sr	96±1%	96±1%
	^{152}Eu	7±2%	10±4%
Concrete	^{137}Cs	67±12%	54±9%
	^{85}Sr	52±22%	40±10%
	^{152}Eu	20±3%	8±8%
Brick	^{137}Cs	33±2%	33±7%
	^{85}Sr	58±5%	32±7%
	^{152}Eu	0±3%	1±3%

Low Pressure Flow Tests on Other Building Materials using Tap Water

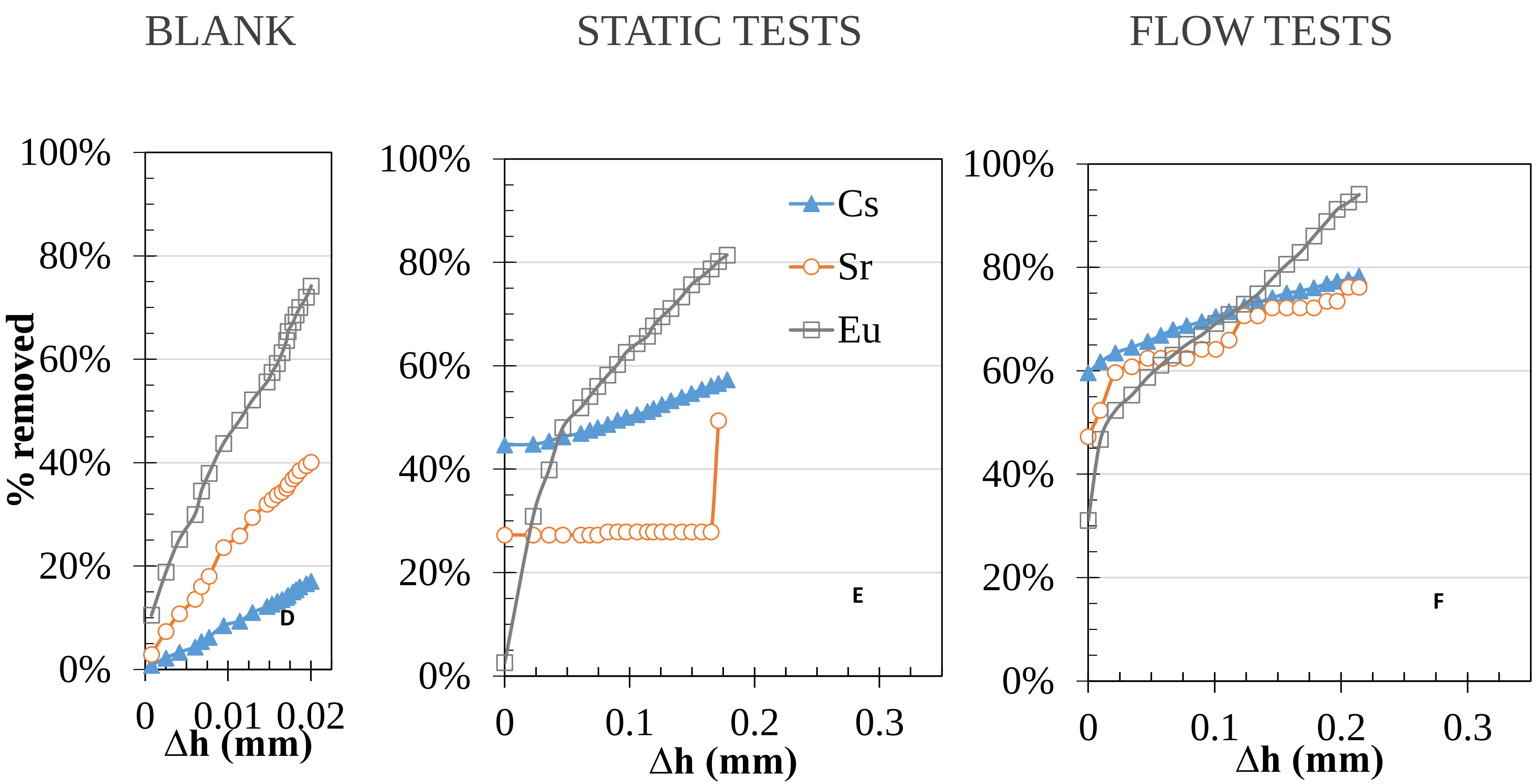
- High ^{85}Sr removal for the shingles similar asphalt roadway coupons.
- ^{152}Eu was slightly more persistent on the asphalt, suggesting formation of an insoluble precipitate.
- Removal from painted wood using tap water were 10-20%, due to the penetration/bonding of the radionuclides.
- Shingles and painted wood with 0.1 M KCl solution.
  - No measurable effect on the results for ^{152}Eu and ^{85}Sr
  - ^{137}Cs improved from 22±5% to 54±2% using 0.1M KCl on shingles
  - ^{137}Cs improved from 11±2% to 37±11% for painted wood.



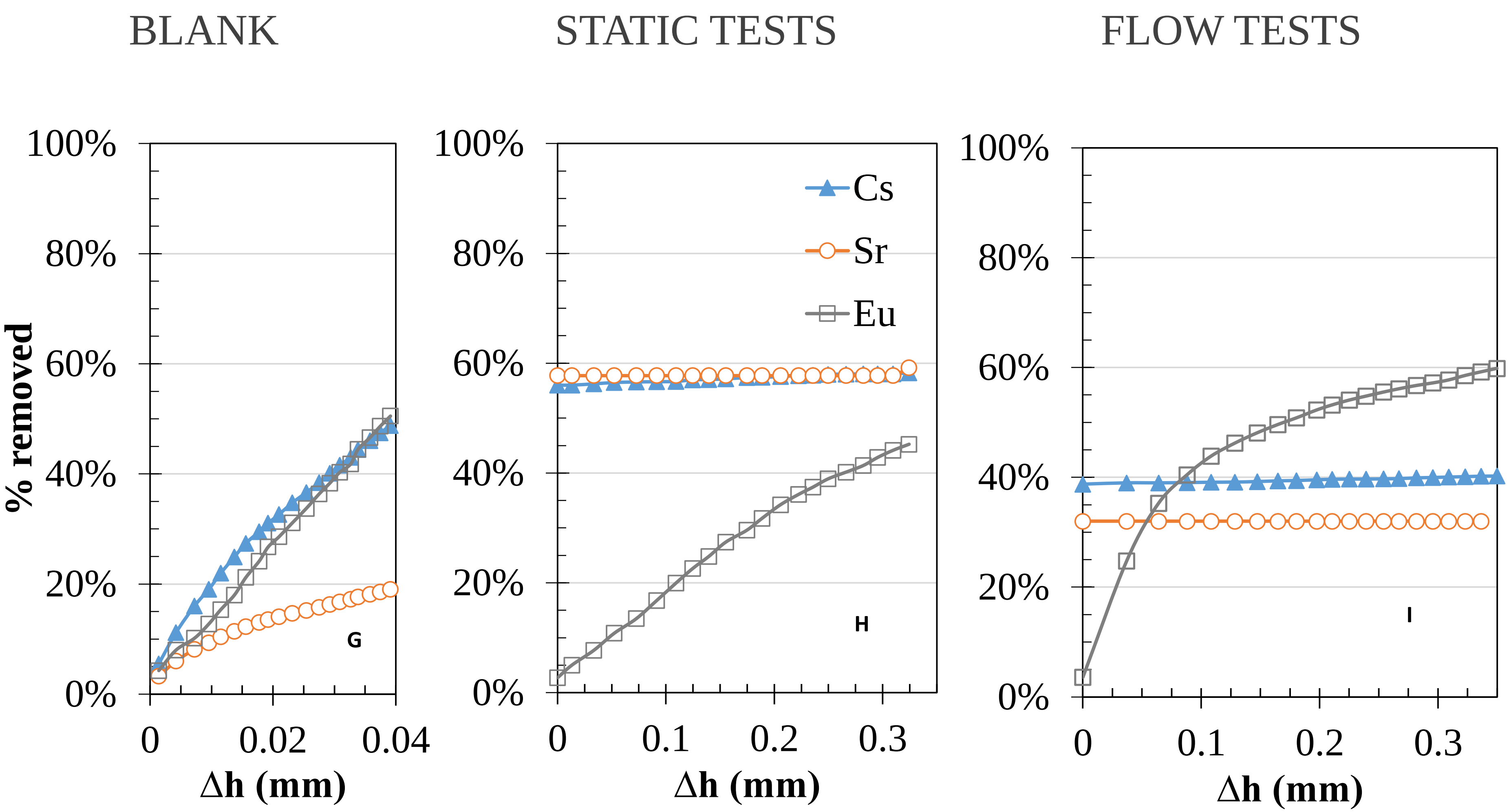
Depth of Contamination in Asphalt



Depth of Contamination in Concrete



Depth of Contamination in Brick



Wash Penalty Factors

- Washing the surface can *increase* the depth of contamination, depending on the wash conditions.
- Although advantages are afforded by washing and removing a percentage of the initial contamination, enhancing the penetration of the residual contamination can complicate long-term remediation efforts by making it more difficult to remove the radioactivity to meet long-term remediation goals.
- To quantify this undesirable outcome, we introduce the concept of a wash penalty factor (WPF).
- This can be defined as the depth at which 50% (or some other target decontamination factor) of radioactivity is found in the washed sample divided by the depth at which 50% of radioactivity is found in the control.

Wash Penalty Factors

- A WPF > 1 would indicate that despite being able to reduce the radioactive contamination on the surface by the wash method, the depth of the contamination to obtain our target decontamination goal is enhanced by a factor equal to the WPF.
- If the $0 < WPF < 1$ then the wash method is able to achieve the decontamination without promoting contamination deeper into the surface.
- A WPF = 0 denotes that the wash test method alone was able to remove the radioactivity to the target value, and there was no penalty from using the wash method.

Wash Penalty Factors

- For example, 50% of ^{137}Cs was within the first 0.01 mm of the asphalt surface in our control. Using the depth in the flow test sample at which 50% of the ^{137}Cs (0.035 mm) is found yields a WPF = 3.5:

  $$WPF_{50\%} = 0.035\text{ mm}/0.01\text{ mm} = 3.5.$$

- This value expresses that the depth at which 50% of the radioactivity can be removed is increased by a factor of 3.5 when the flow wash method is applied.
- Using this approach for asphalt,
  - $WPF_{50\%} = 0$ for ^{85}Sr (0 mm/0.012 mm)
  - $WPF_{50\%} = 5.8$ for ^{152}Eu (0.035 mm/0.006 mm)

Summary

- Tap water was very effective in decontaminating all the radionuclides from glass, vinyl siding, and painted metal given their hard, non-porous surfaces.
  - However, removal of these radionuclides from painted wood benefited from addition of KCl.
- The asphalt shingles behaved similarly to the asphalt pavement samples where ^{85}Sr could be removed by tap water,
  - yet potassium salt water was still ineffective in removing ^{137}Cs and ^{152}Eu.
- Low-pressure flow tests mimic the action of fire hosing and represents a practical application method in the field.
  - Potassium salt significantly improved decontamination of ^{137}Cs but less so with ^{85}Sr.
  - Moreover, there was no discernible difference in decontamination between 0.1M KCl and 0.5 M KCl.
  - ^{152}Eu was not effectively removed by either wash method even with addition of potassium salt.
    - Insoluble precipitate of europium, and its removal via dissolution using mineral acid corroborated this notion.

Summary (cont.)

- Even with higher data scatter, this study suggests that removal of ^{137}Cs from brick was significantly improved by soaking the surface in the static test rather than the short exposure to wash solution provided by the low-pressure flow test format.
- Wash penalty factor (WPF) concept may be valuable when systematically considering decontamination options and for helping set operational conditions for water washing.
  - For example, considering the practical choice of a low-pressure wash with K^+ additive, the $WPF_{50\%}=0$ for ^{85}Sr suggests the effectiveness of this technique for many building materials.
  - ^{152}Eu could not be removed effectively with $WPF_{50\%}=2.7$-6.5, implying more aggressive techniques are necessary, such as mild, physical ablation afforded by a pressurized wash
  - Low-pressure washing of concrete was effective for cesium contamination ($WPF_{50\%}=0$), while it significantly promoted movement of radioactivity into the building materials for asphalt ($WPF_{50\%}=2$) and brick ($WPF_{50\%}>7.7$).

Acknowledgments

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