Irreversible Wash-Aid, Treatment, and Emergency Reuse System (IWATERS): Ad-Hoc Systems for On-site Treatment of CBRN Contaminants from Wash Waters

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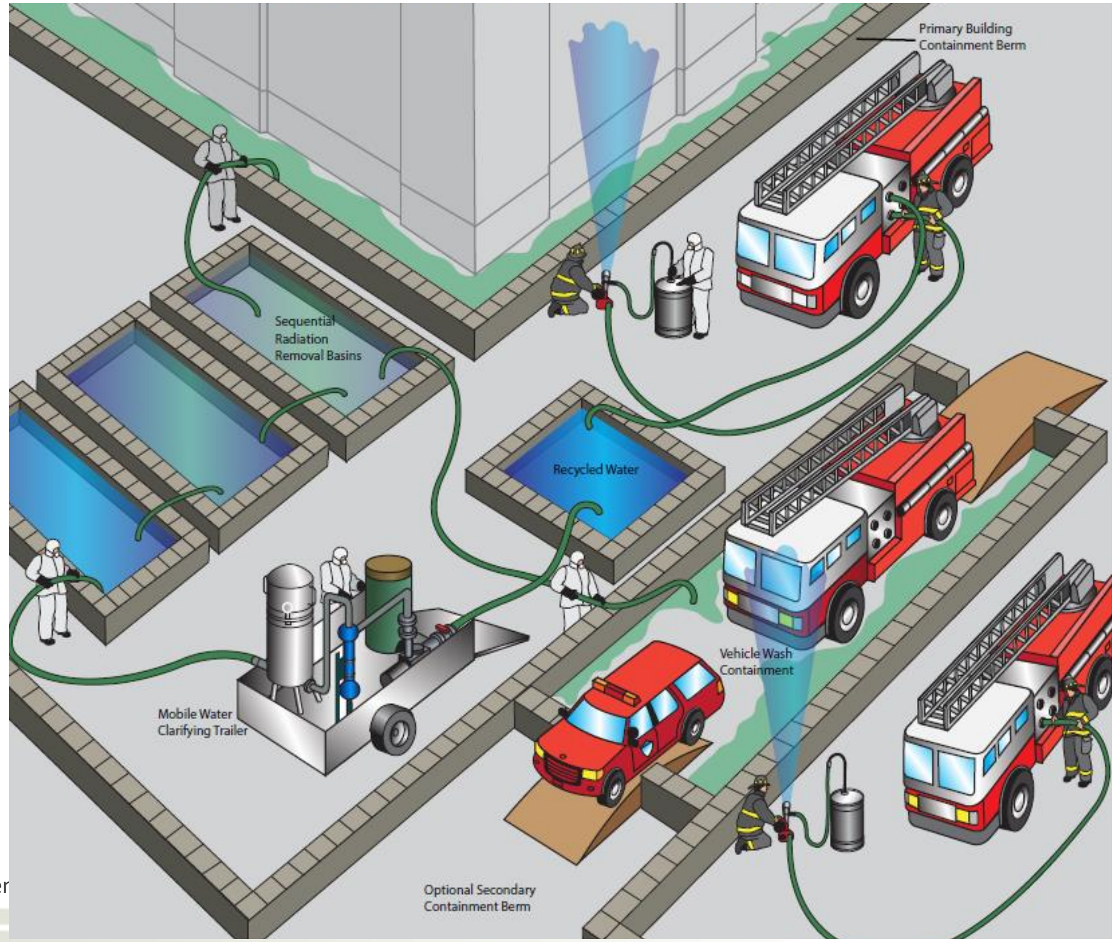
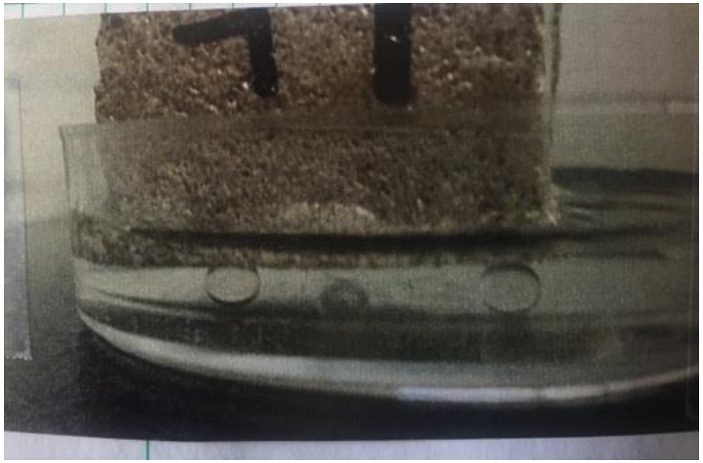
IWATERS

- In partnership with the USEPA, DOD, and DHS we have been developing a decontamination system for wide-area mitigation and remediation activities. This Integrated Wash-Aid, Treatment, and Emergency Reuse System (IWATERS) is designed for soluble and particulate contaminants.
- Components of the technology are:
  – Worker-friendly wash aid additives to tap water to promote the ion exchange of radionuclides from the surface
  – Capture and containment of the contaminated runoff
  – Use of sequestering agents to remove the dissolved radionuclides from the wash water
  – Filtration and reuse of the wash water for continued operations

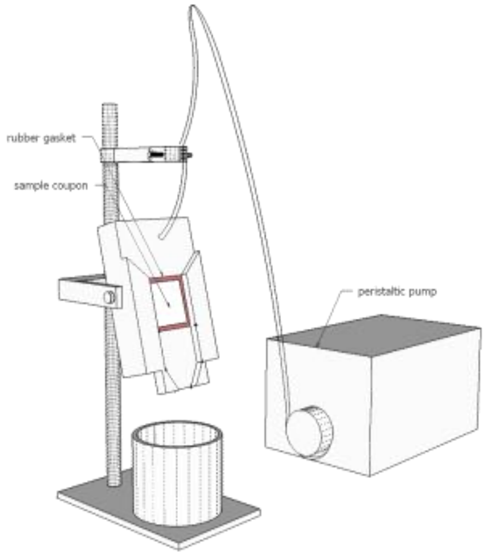


Test scheme

- Sorption/desorption tests to screen potential wash aid additives
  - Sr-85, Cs-137, Eu-152 (surrogate for americium).
  - Batch tests on aggregate or crushed material to understand sorption kinetics.
  - Coupon static tests on down-selected wash additives to determine the decontamination factors (DF).
  - Coupon low pressure flow tests to better simulate in-field conditions and determine DF.
  - Coupon high pressure flow tests to understand effect of higher pressure wash on DF.



Static test with concrete coupon suspended in wash solution

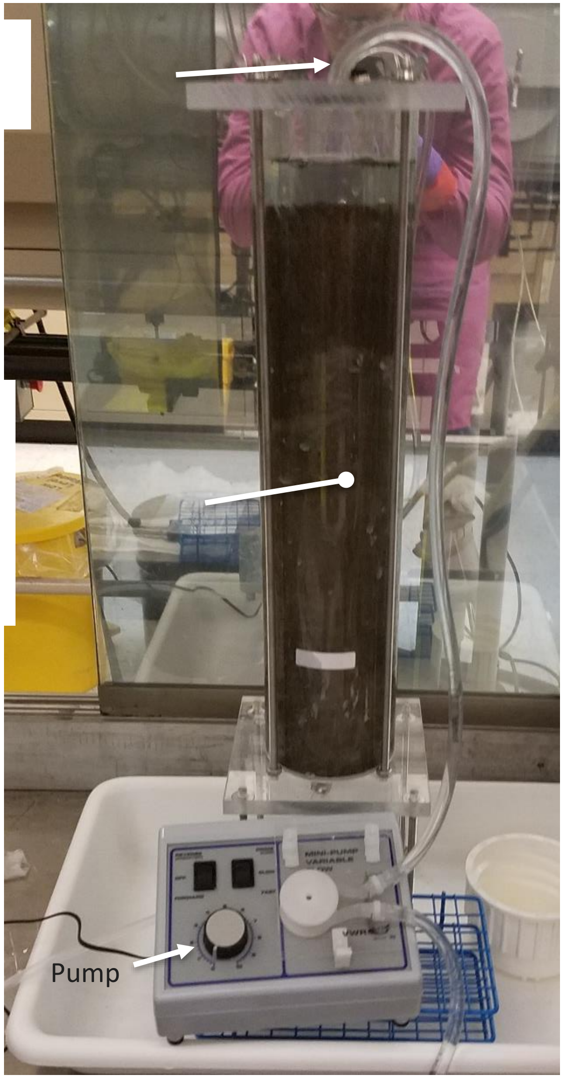


Schematic of flow system. A wash solution is pumped over the coupon and into a beaker.

High pressure flow test chamber allows us to vary the spray pressure and coverage rates.

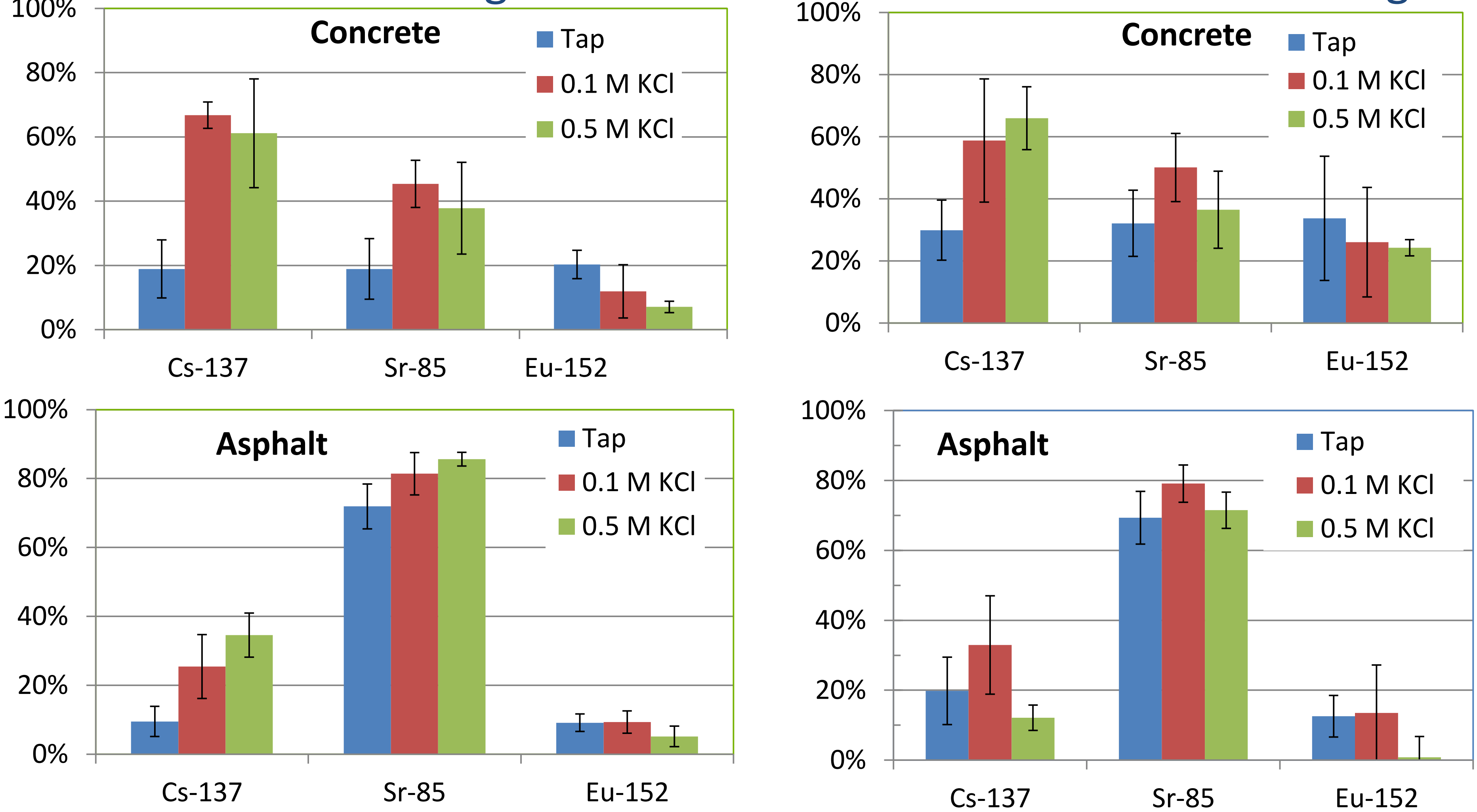
Test scheme (cont.)

- Contaminated water needs to be contained and processed.
  - Ideally, processing occurs in situ.
- We evaluate sorbents in batch and column flow tests to determine the sorption coefficients (K_d).
- Contaminated water is passed through columns containing reactive (e.g., clays, activated carbon) and inert materials (e.g., sand).
- The data is used to design filtration beds for treatment in the field.



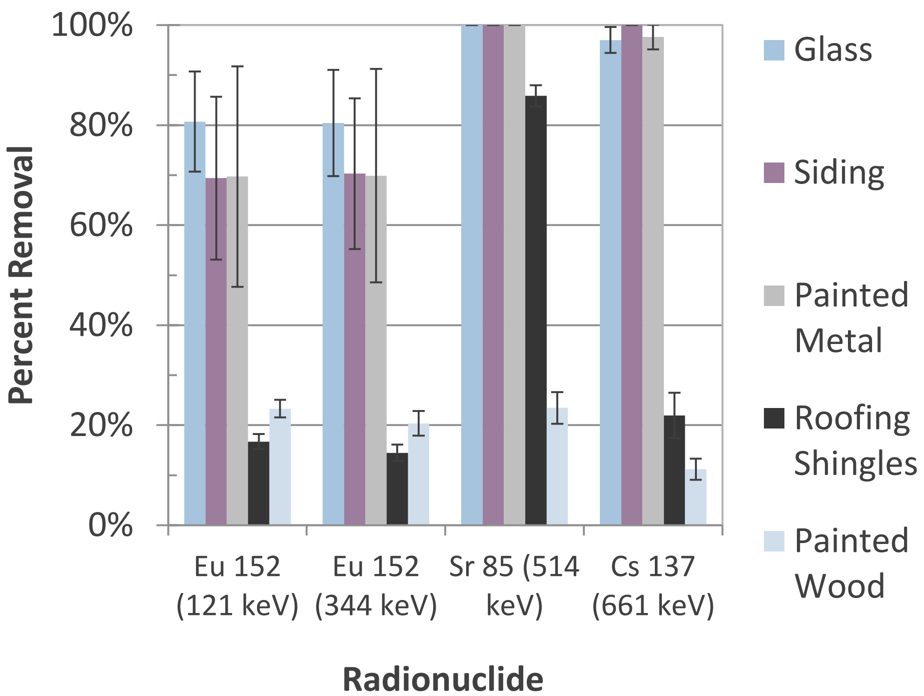
Static Testing

Low-Pressure Flow Testing

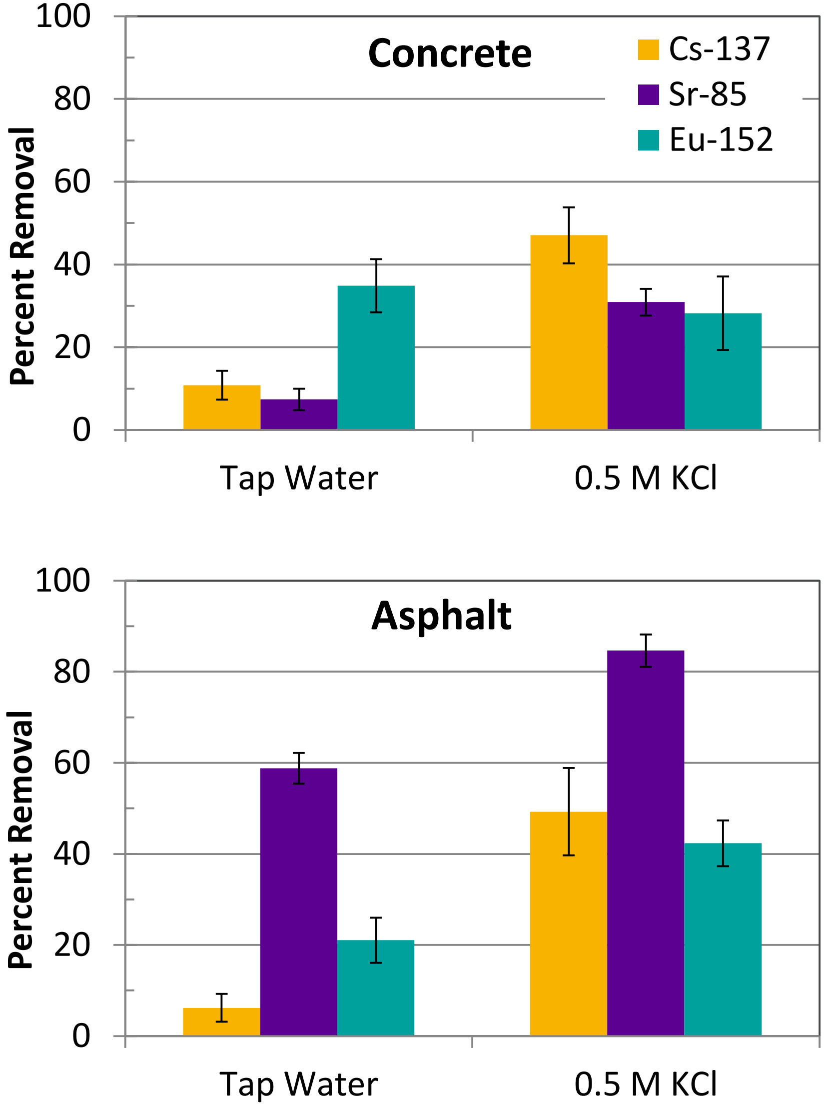


- Potassium additive improves decontamination of cesium but not strontium or europium (all radionuclides deposited as salts in water).

Low-Pressure Flow Testing (cont.)



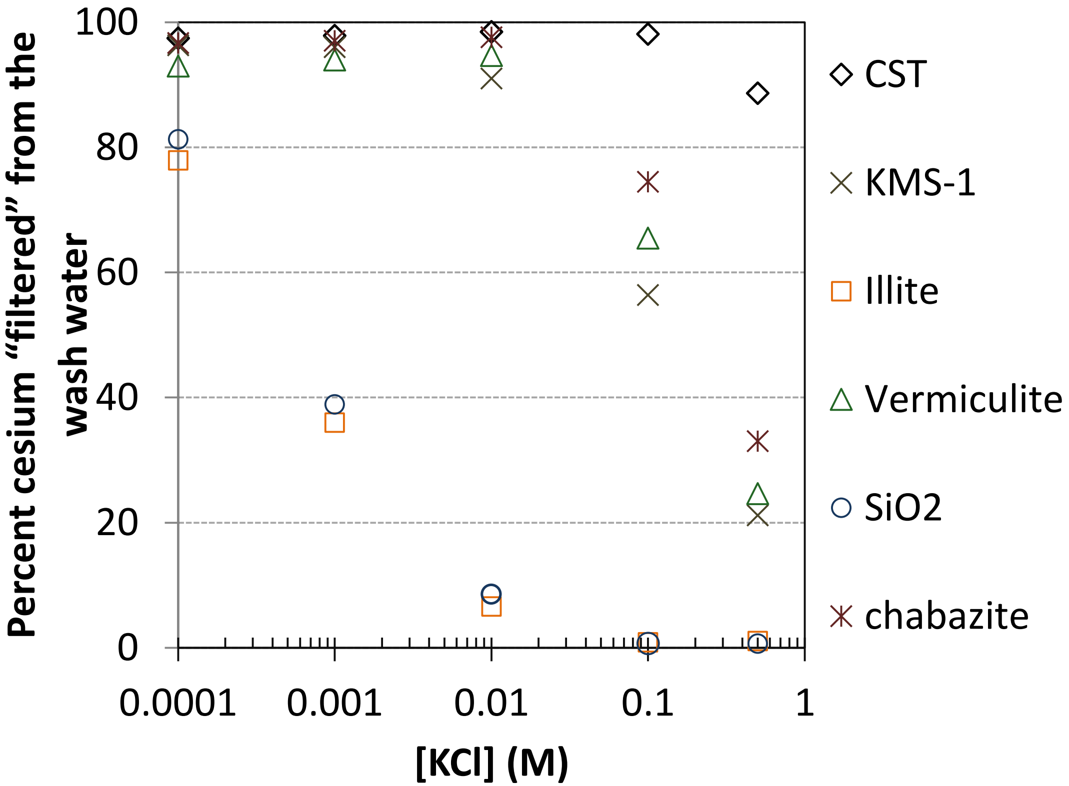
High-Pressure Flow Testing



- Unmodified tap water was effective on some common, non-porous surfaces.
- High-pressure flow tests on concrete show that potassium additive improves decontamination for cesium and strontium. On asphalt, potassium improves decontamination for all radionuclides.

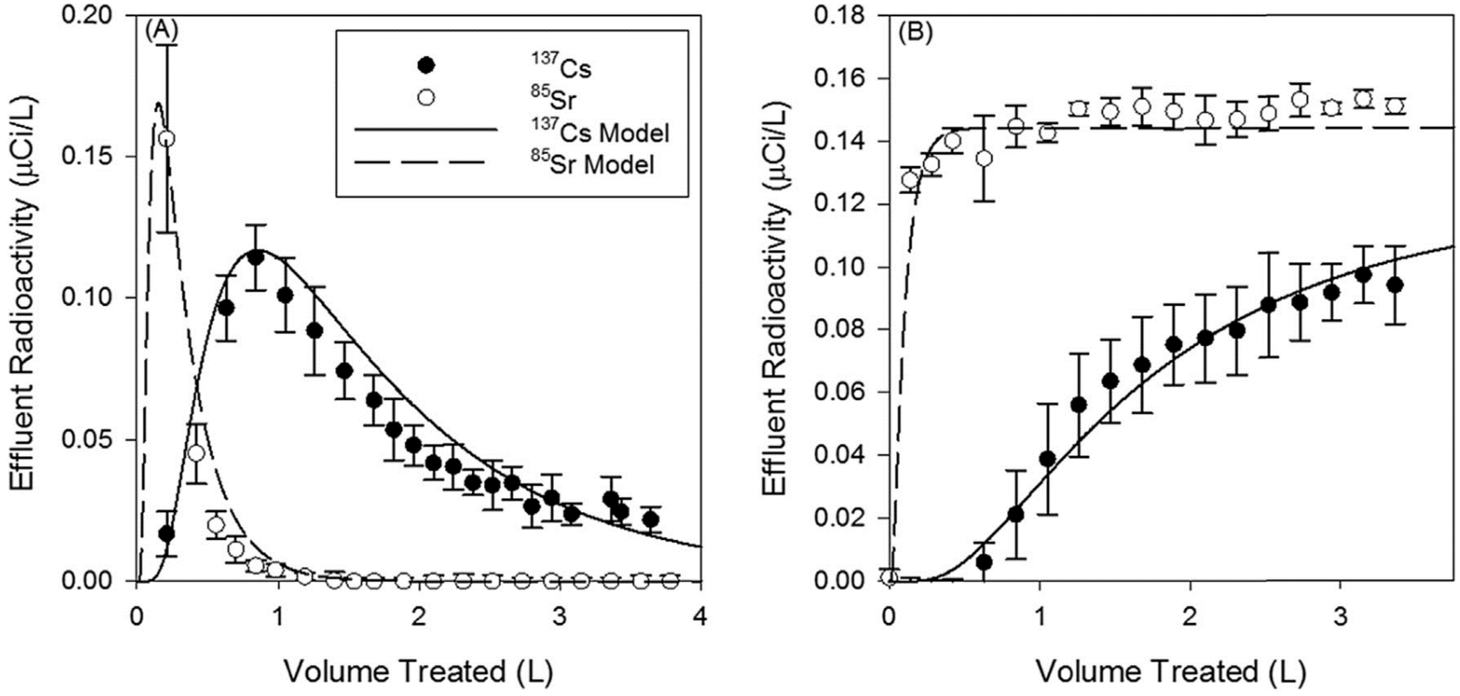
Sequestration agents for cesium for water recycle in reactive filtration beds

- Once removed from the building materials, the contaminated wash water must be treated to remove the radionuclides.
  - Identify common sorbents that can be gathered in bulk for immediate use.
  - Tested many common clays, soils, gravel, crushed building materials, and specialized-engineered sorbents.



Input into computer model

- With reliable filtration data (K_d), we can model the "filtration" of radionuclides and design full-sized filtration beds to process a given volume of wash water.



GoldSim modeling of contaminated wash water

$$m'_{is} = -m_{is}\lambda_s + \sum_{p=1}^{NP_s} m_{ip}\lambda_p f_{ps} R_{sp}\left(\frac{A_s}{A_p}\right) + \sum_{c=1}^{NF_i} f_{cs} + S_{is}$$

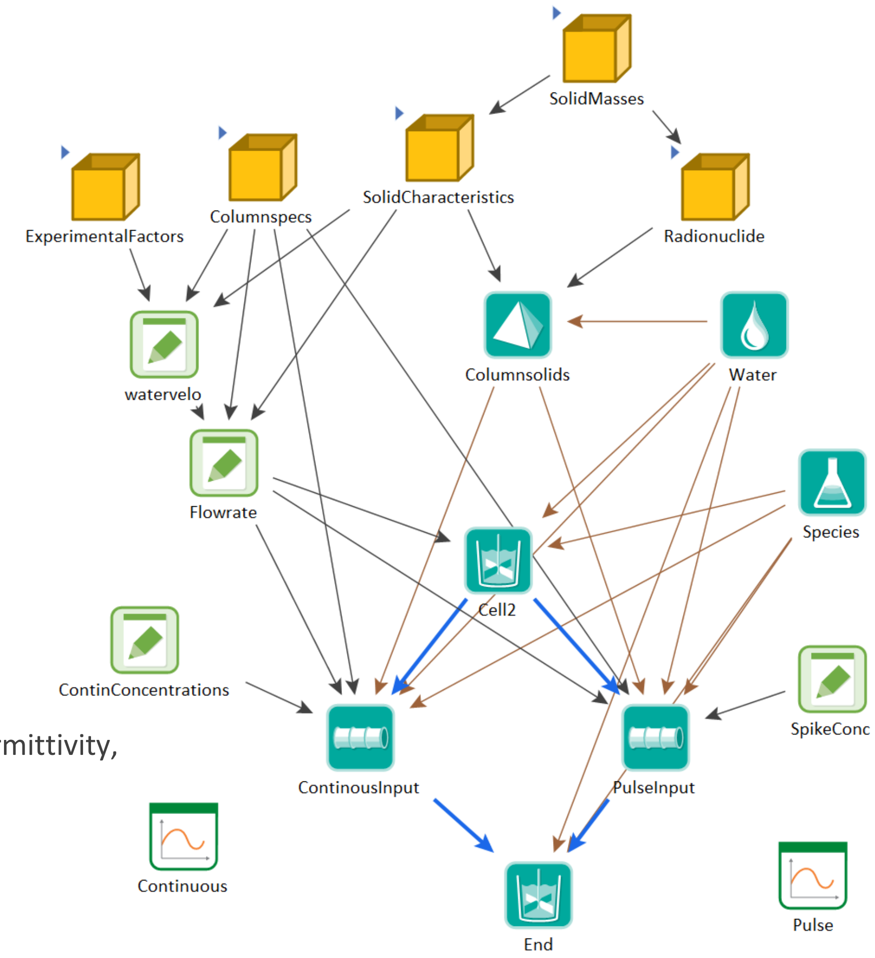
m'_{is} is the rate of mass increase in cell i of species s (e.g., $^{137}Cs^{+}$ or $^{90}Sr^{2+}$),

f_{cs} is the mass rate into cell i of species s through link c from all mass flux units NF linked to cell i, and

S_{is} accounts for "external" source inputs

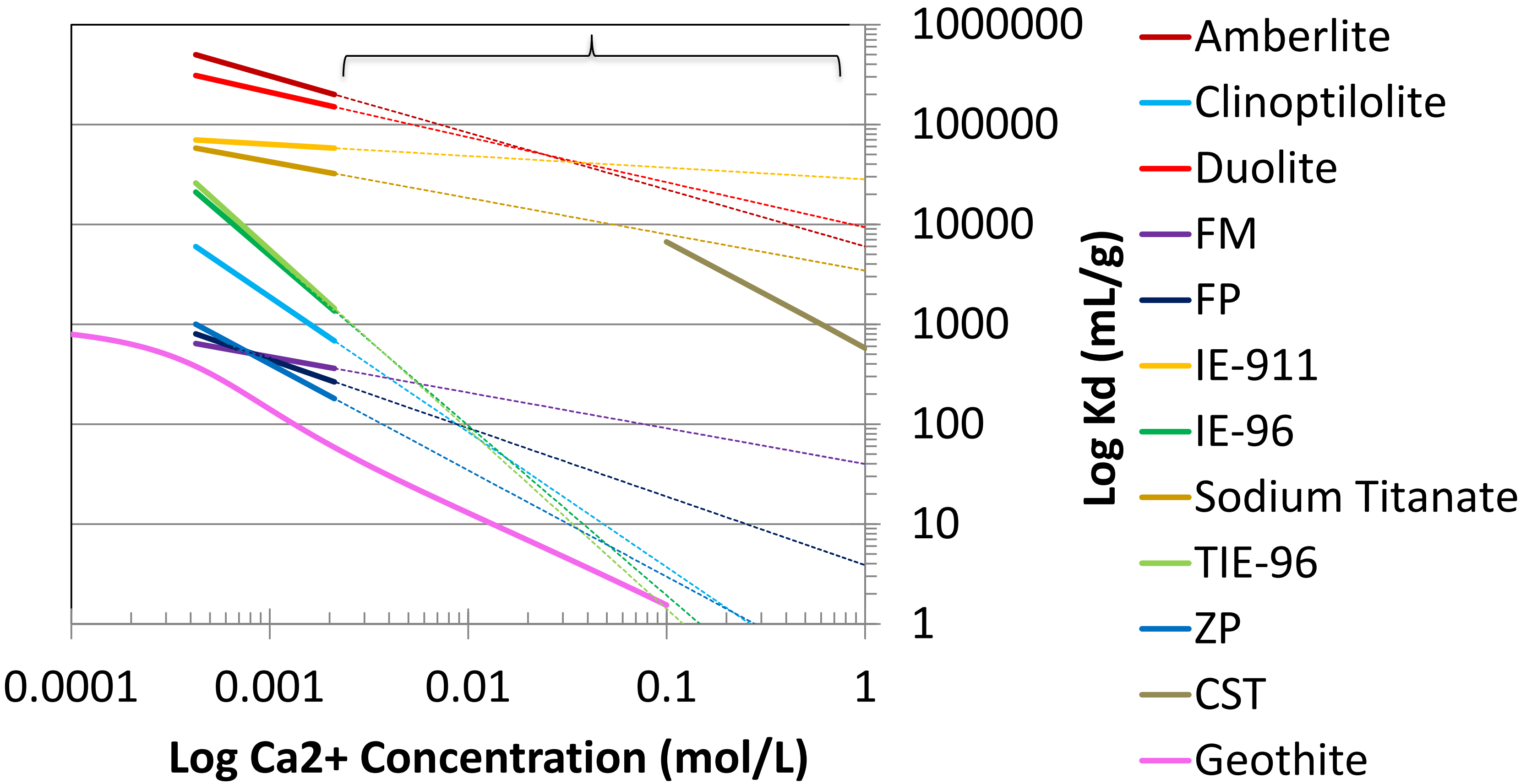
$$m'_{is} = \sum_{c=1}^{NF_i} f_{cs} + S_{is}$$

- "ExperimentalFactors" (head height of water)
- "Columnspecs" (height and surface area of the sorbent bed)
- SolidCharacteristics (composition of bed and the bulk density, permittivity, and porosity of its components),
- "Radionuclide" (sorbent-dependent sorption coefficients K_d)
- "Water" (diffusivity)
- "Species" to be tracked (^{137}Cs),
- The concentration of incoming species ("ContinConcentrations" for continuous feed at a given concentration or "SpikeConc" for a single injection of a concentrated bolus).



- Model calculates the gravity-fed flow velocity and the time-dependent concentration of radionuclides in the bed and effluent.

Filtration of strontium contaminated waters



Look Up Tables

- Simplifying these tables into a GUI asks the user simple questions
  - How much water they expect to process?
  - Over what period of time?
  - What sorbent materials are available?
- Can be adapted into a phone application that could be implemented in the field.

Ad hoc filtration beds for processing cesium-contaminated fresh (tap) water.

Wash Water: Tap				
Sand:Clay				
Ratio ↓	Hours	mCi	Gallons	Gal/min
50:50	91.9	53.95	142571	25.9
60:40	64.0	45.26	119602	31.1
70:30	42.9	35.53	93897	36.5
80:20	26.1	24.75	65414	41.8
90:10	12.1	12.93	34206	47.2

Ad hoc filtration beds for processing cesium-contaminated salt (0.1 M KCl) water.

Wash Water: 0.1 M KCL				
Sand:Clay				
	Hours	mCi	Gallons	Gal/min
50:50	5.1	3.005	7965	25.8
60:40	3.6	2.534	6726	31.0
70:30	2.4	2.001	5322	36.3
80:20	1.5	1.408	3762	41.6
90:10	0.7	0.768	2076	47.0

Look Up Tables (cont.)

Ad hoc filtration bed calculator for processing contaminated salt (0.1 M KCl) water.

Table 1	Hours	mCi	Gallons	Gal/min
SA ↑	No Effect	multiply by Total Sqft/100		
Depth ↑	x4(Depth-1)	x2.5(Depth-1)	x2.5(Depth-1)	/.8(Depth-1)

Wash Water: 0.1 M KCl	400 x 3			**Table 2**
Sand:Clay Ratio ↓	Hours	mCi	Gallons	Gal/min
50:50	41.1	60.1	159301	64.4
60:40	28.8	50.68	134516	77.6
70:30	19.5	40.02	106435	90.8
80:20	12.0	28.16	75236	104.1
90:10	5.9	15.36	41517	117.5

Rain barrels to clean contaminated water generated during roof wash-down activities

- This barrel contained a 70:30 mixture of sand:clay (2.75 ft^2 x 2 ft depth)
- Capable of processing
  - >7000 gallons of tap water with cesium, or
  - >400 gallons of 0.1 M KCl in tap water.
  - 80 gal/h (300 L/h) before breakthrough
- Residential crew for a neighborhood?

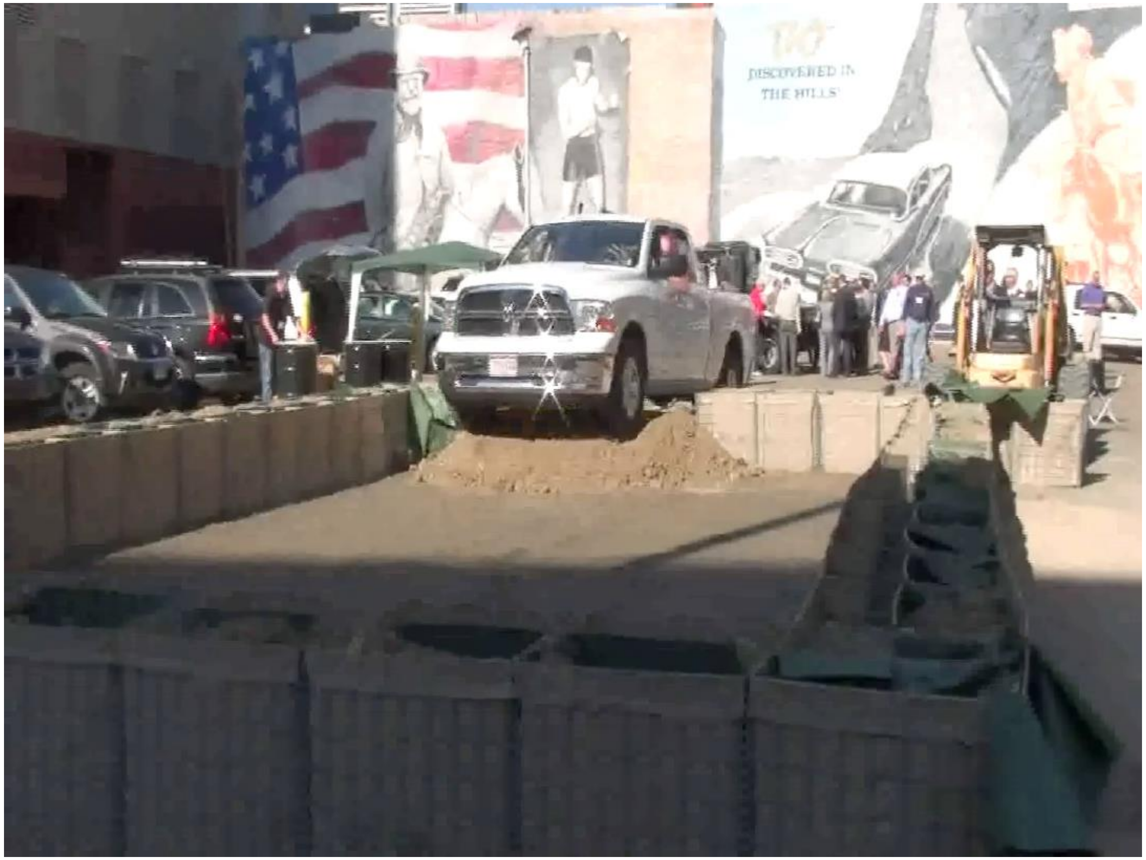
Gutter channels water to the barrel

Height of filter bed mixture

Drain tile at the bottom of the barrel helps clarify effluent

Vehicle decontamination basin to treat contaminated runoff from vehicle decontamination

- The flood barriers are designed to be driven over to allow vehicle entry.
- Containing a mixture of 70:30 sand:clay (600 ft^2 x 1 ft depth),
- Can treat
  - >500,000 gallons of tap water with cesium or
  - >31,000 gallons of 0.1 M KCl in tap water before experiencing breakthrough.
  - 13,000 gal/h (49,000 L/h)
- Egress routes?



Building runoff basin

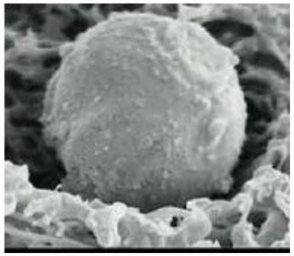
- Constructed by attaching tarps to the building façade using wood strips and powder actuated fastener
- This basin was filled with 70:30 sand:clay (540 ft^2 x 1 ft depth)
- Can treat
  - >1.4 million gallons of tap water with cesium or
  - >80,000 gallons of 0.1 M KCl in tap water before breakthrough.
  - At a rate of 15,000 gal/hr.
- City-wide decontamination activities

Biological contaminants

- Verification of the Separmatic™ DE Pressure Type Filter System 12P-2.
- Six *Cryptosporidium oocyst* challenges and one control challenge were performed.
- Processed 35,000 gallons of treated water over 360 hours of operation during the EPA Environmental Technology Verification Testing (sample results below).

Table VS-1. *Cryptosporidium* Oocyst Challenge Test Sample Results

Set No.	Date	Time Description	Average Feed Oocysts (#/20L)	Average Effluent Oocysts (#/20L)	Log_{10} Removal Oocysts
1	5/14/03	1.5 hours	2.2 x 10^6	891	3.4
1	5/14/03	85% Headloss	1.5 x 10^6	1270	3.1
2	5/19/03	1.5 hours	1.6 x 10^6	38	4.6
2	5/20/03	85% Headloss	2.0 x 10^6	32	4.8
3	5/28/03	1.5 hours	2.8 x 10^6	19	5.2
3	5/28/03	85% Headloss	2.0 x 10^6	381	3.7



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https://archive.epa.gov/nrmrl/archive-etv/web/pdf/nsf0401epadwctr.pdf

Chemical contaminants

- Using the Separmatic™ System shown (right), common sorbents are being evaluated by the EPA for removal of chemical contaminants.
- Some common sorbents being tested include
  - granulated activated carbon,
  - diatomaceous earth,
  - and porous aluminum silicate.
- Surrogates for chemicals of interest include
  - diazinon (thiophosphoric acid ester; an insecticide),
  - dimethylnaphthalene (DMEN, polycyclic aromatic hydrocarbon; a component of diesel fuel), and
  - dinitroanisole (DNAN; a component of an explosive).
- Tests are ongoing with reports coming.

Summary

- IWATERS can decontaminate buildings, roadways, vehicles, aircraft, runways, etc., using tap water and tap-water-containing mild additives, depending on the type of contamination.
- Waste water can be treated on-site by a combination of natural sorbents and off-the-shelf filter systems for a variety of nuclear and radiological contaminants.
- Modeling suggest that ad hoc IWATERS designs could treat millions of gallons of contaminated waters suitable for reuse.
- The approach can be applied generically to all types of radionuclide contaminants, provided the sorption coefficient (K_d) is known.
- Look-up tables can be used to provide immediate specifications on the design of suitable filtration beds.
  - effectively remove contaminants on currently available materials, such as clays, soils, gravel, crushed lime, and specialized sorbents.

Summary (cont.)

- With such information, we hope to mitigate the effects of generating large volumes of contaminated waters and provide a means of rapidly initiating decontamination activities to restore critical infrastructure and the urban environment.
- We continue evaluating the IWATERS for contaminants to suggest options for
  - Increasing the decontamination of various radionuclides and surfaces.
  - Treating the wastewater with readily available reactive materials, given the geographic or logistical constraints of a particular situation.
  - Optimizing designs of the entire system and providing guidance on site-specific implementation.
  - Integrating the treatment of biological and chemical threat agents to IWATERS using a similar methodology with an effective sorbent/sorption coefficient.

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