



UNIVERSITY OF MINNESOTA DULUTH
Driven to Discover®

Utilizing Northeastern Minnesota Wastewater Treatment Sludge in Heavyweight Concrete for Radiation Shielding

Presented by Kate McCabe
Advised by Dr. Mary Christiansen and Dr. Brian Hinderliter

Wild Rice in Minnesota



[Image 1]

[1]

The biochemical habitat of wild rice – John Pastor (2016)



The biochemical habitat of wild rice – John Pastor (2016)



[Image 2]

The biochemical habitat of wild rice – John Pastor (2016)



“Canary in a coal mine”

Sulfate Water Quality

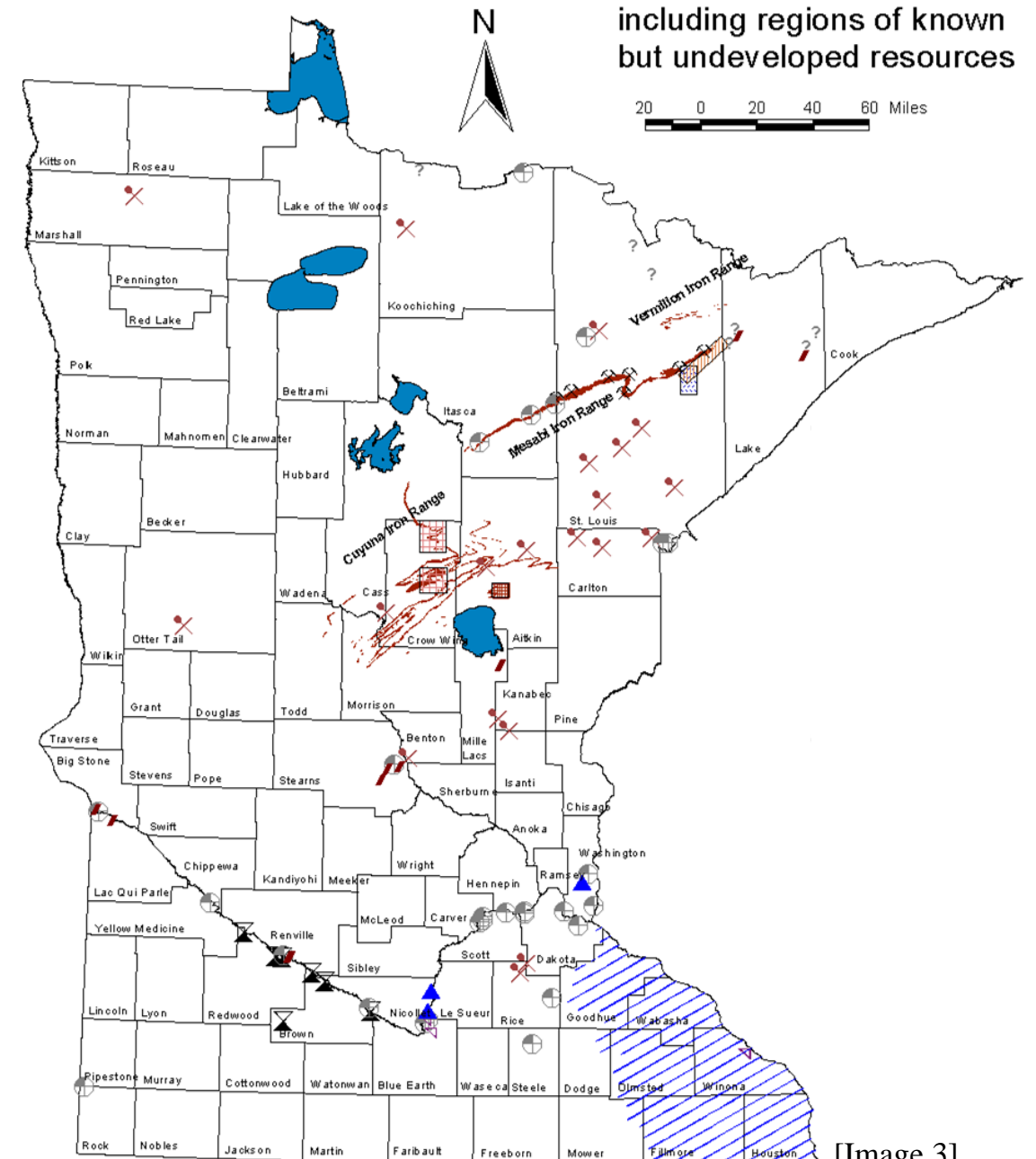
- Minnesota Sulfate Water Quality Standard of 1973
 - Minnesota Pollution Control Agency (MPCA) enforced the standard in 2010
 - Sulfate concentrations as low as 10 parts per million (ppm) in wild rice waters
 - 250 ppm for drinking water

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Iron ranges



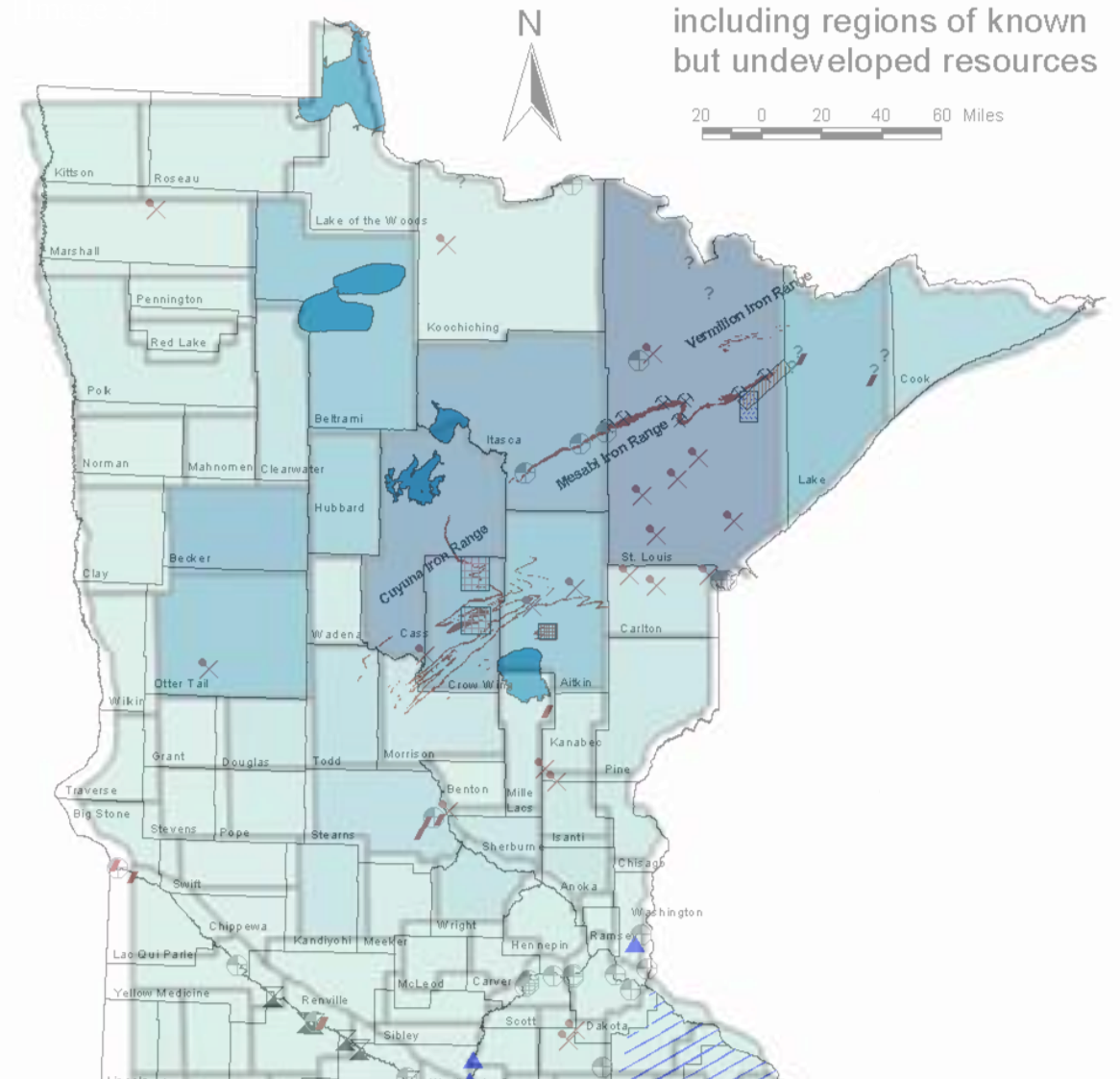
[Image 3]

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Iron ranges



Wild rice waters per county

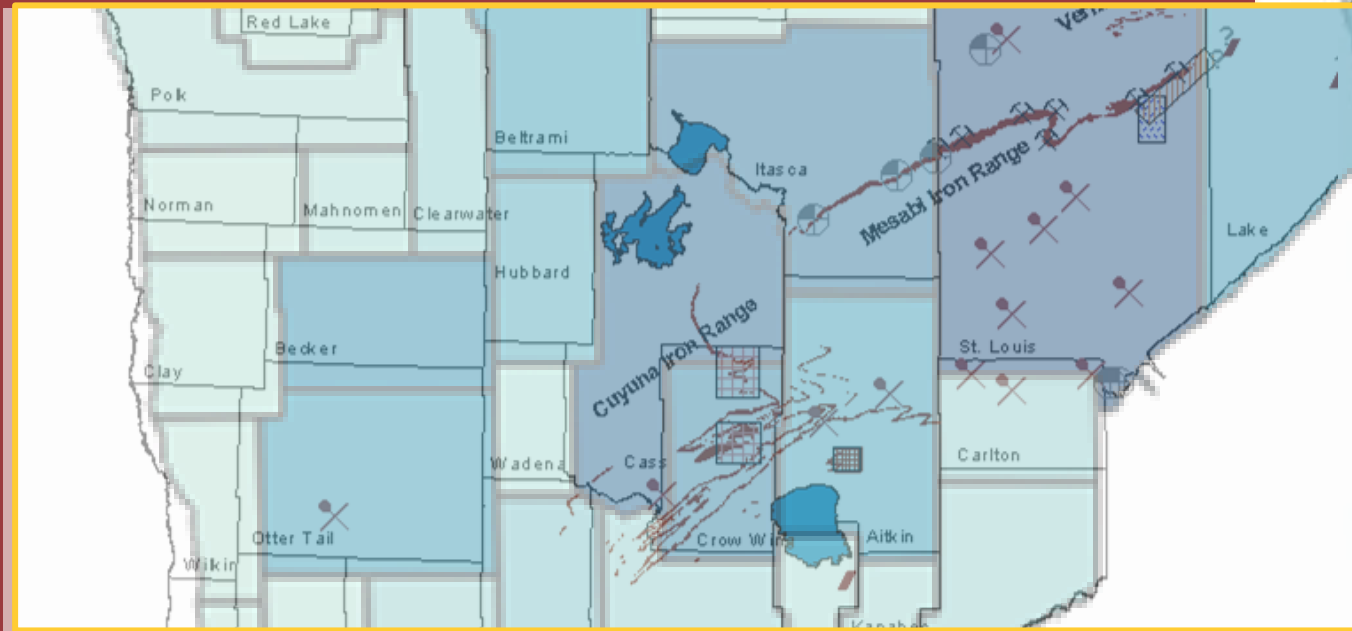
[Image 4]

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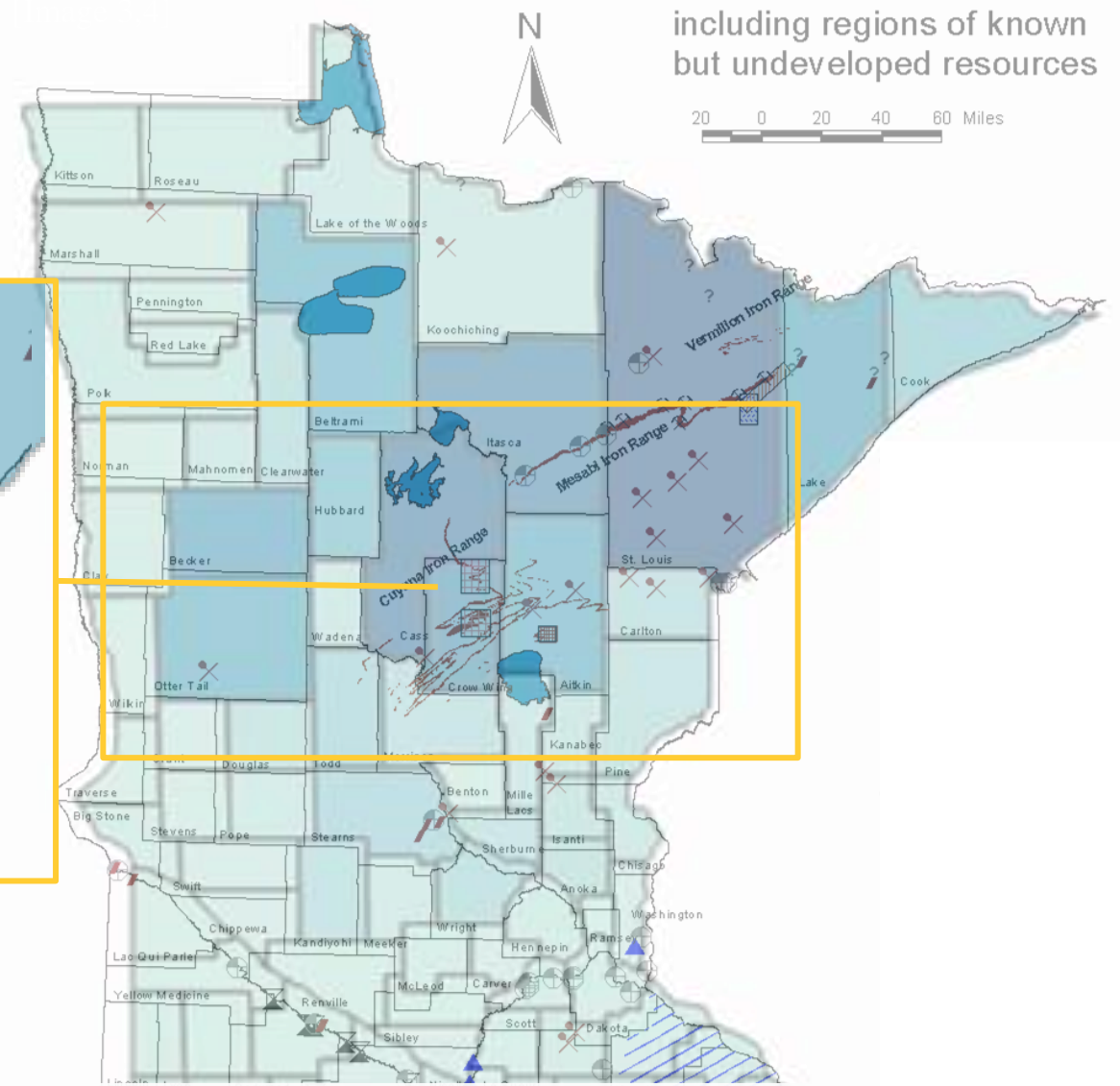


245

Sulfate Water Quality



 Iron ranges



Wild rice waters per county



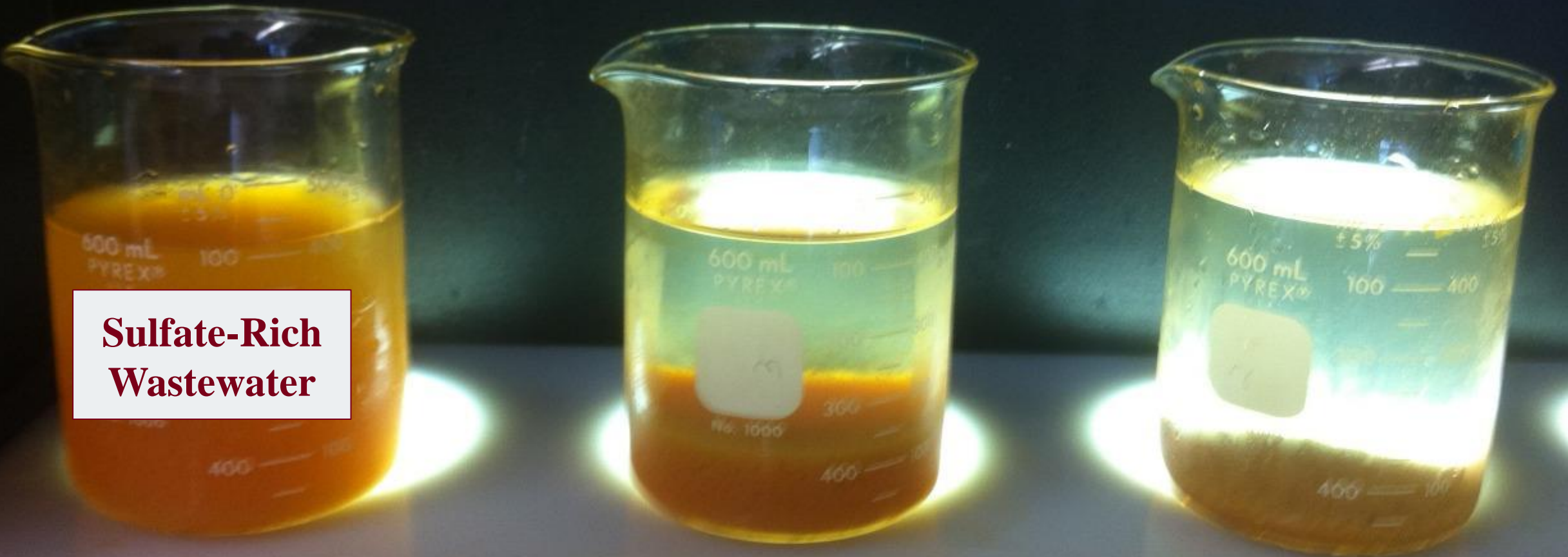
Sulfate Reduction through Chemical Precipitation



[Image 5]

Chemical Precipitation

**Sulfate-Rich
Wastewater**



Chemical Precipitation

Goal: Keep water treatment sludge out of landfills



Chemical Precipitation

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Barium Sulfate

- Barium Sulfate
 - Formed through precipitation
- Barite
 - Mineral form
- White Crystalline solid
- Insoluble in water
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233.39

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 - Specific gravity of 4.0 – 4.4 (ASTM C637, 2020)



233.39

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 - Specific gravity of 4.0 – 4.4 (ASTM C637, 2020)
 - Lab sand specific gravity of 2.6



Barium Sulfate

233.39

Heavyweight Concrete

Heavyweight Concrete:
Measuring, Mixing,
Transporting, and Placing

Reported by ACI Committee 304

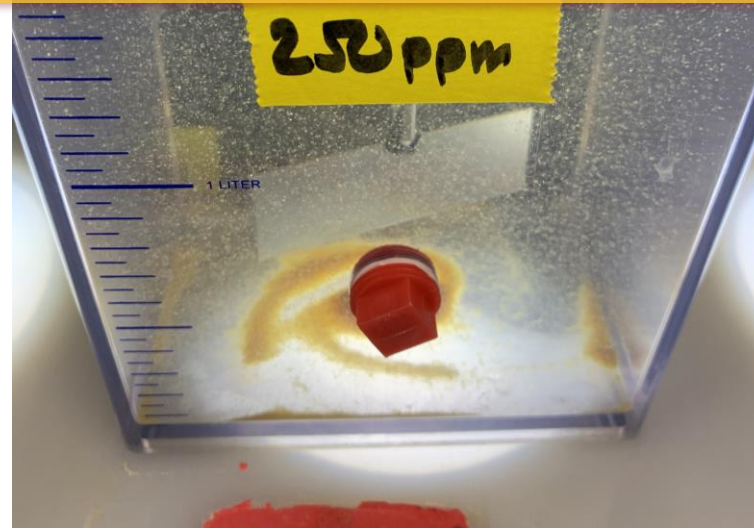
ACI 304.3R-20

- Heavyweight concrete
 - Dependent on aggregate usage
- Barite sand mixture
 - 185 pcf – 205 pcf
 - 5,000 psi – 6,000 psi
- Common applications
 - Counterweights in construction, sound attenuation, radiation shielding

Fine Aggregate Preparation



[Image 8]



[Image 10]

Fine Aggregate Preparation



Pure Lab-Grade Barium Sulfate
(Control)

[Image 8]



Lab Precipitated Barium Sulfate



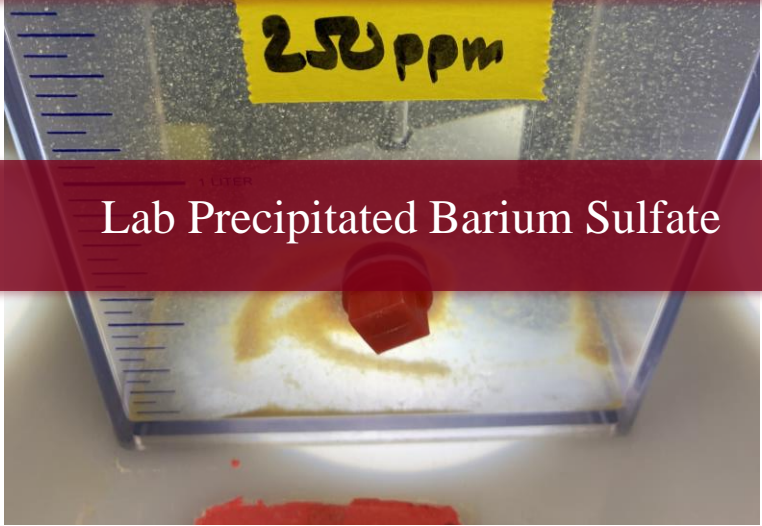
Domestic Wastewater



Industrial Wastewater

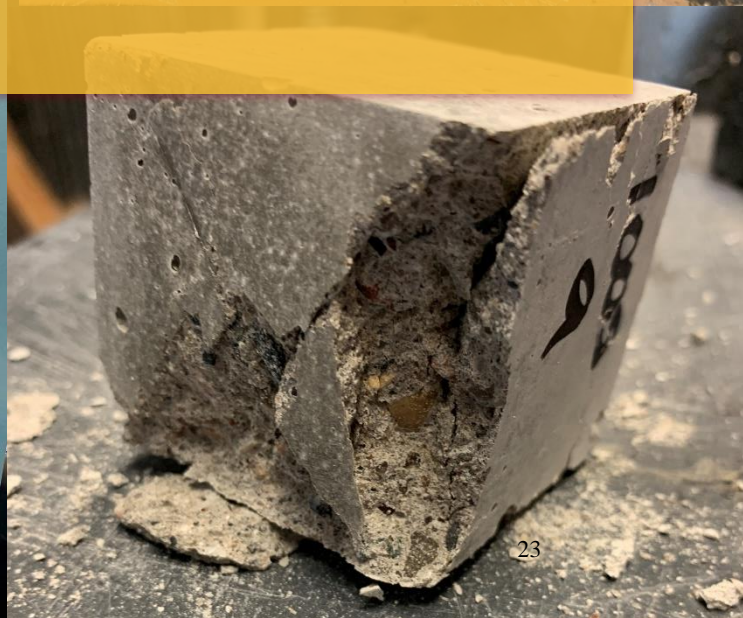
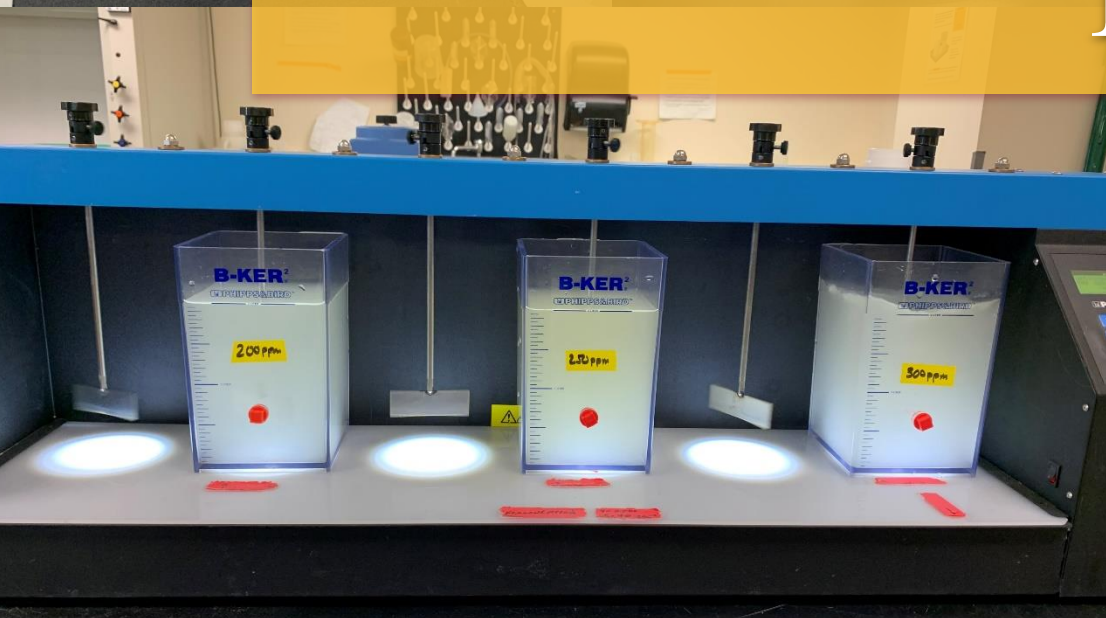
[Image 10]

Fine Aggregate Preparation

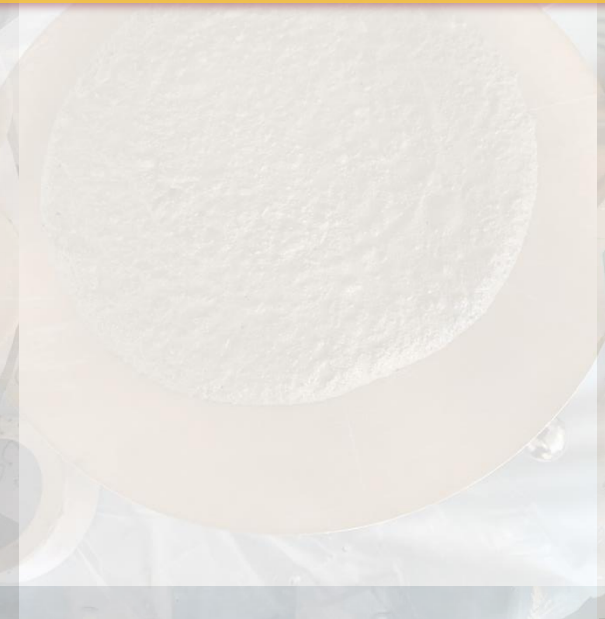
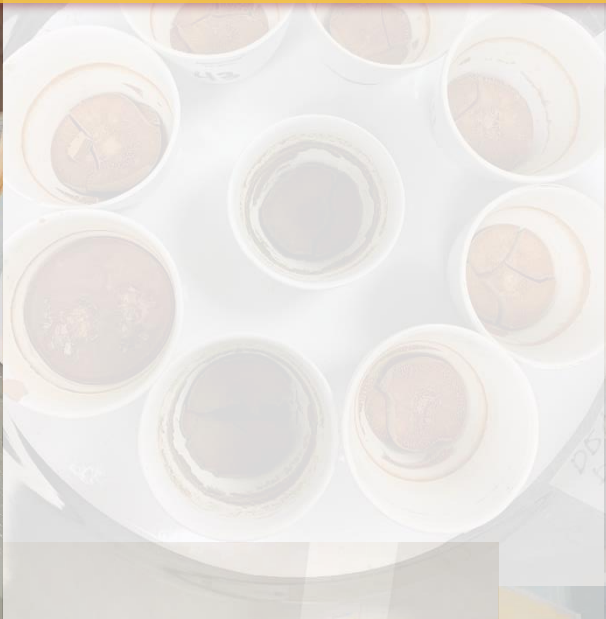
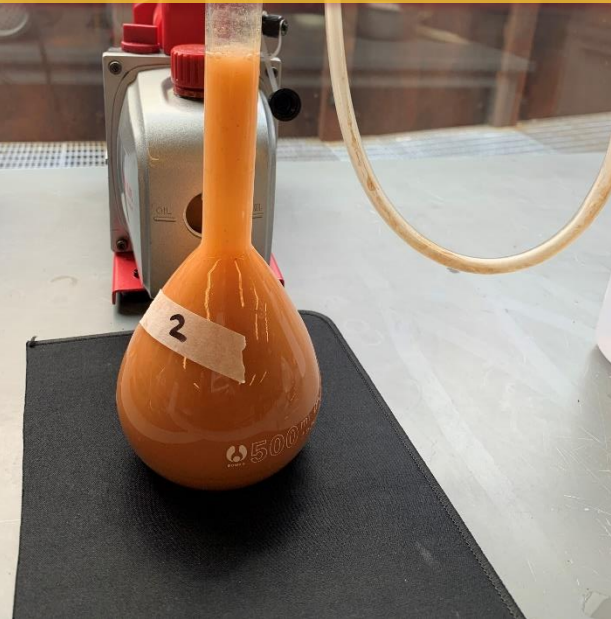




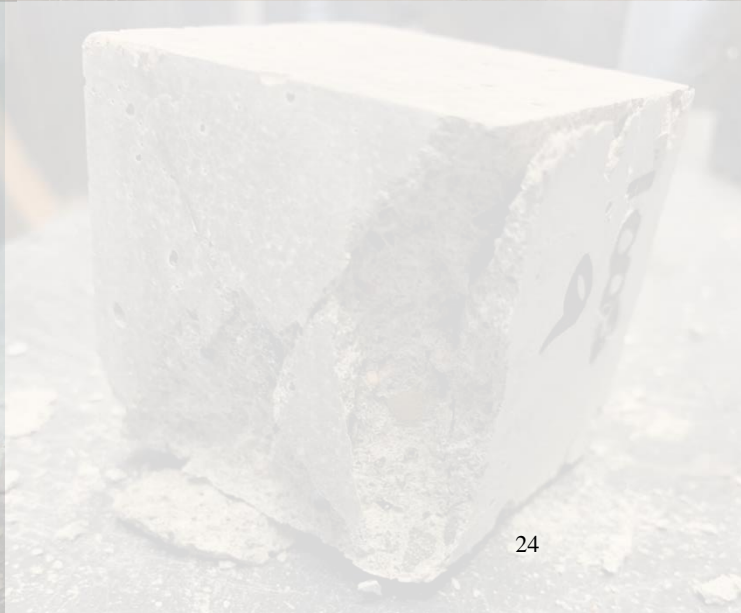
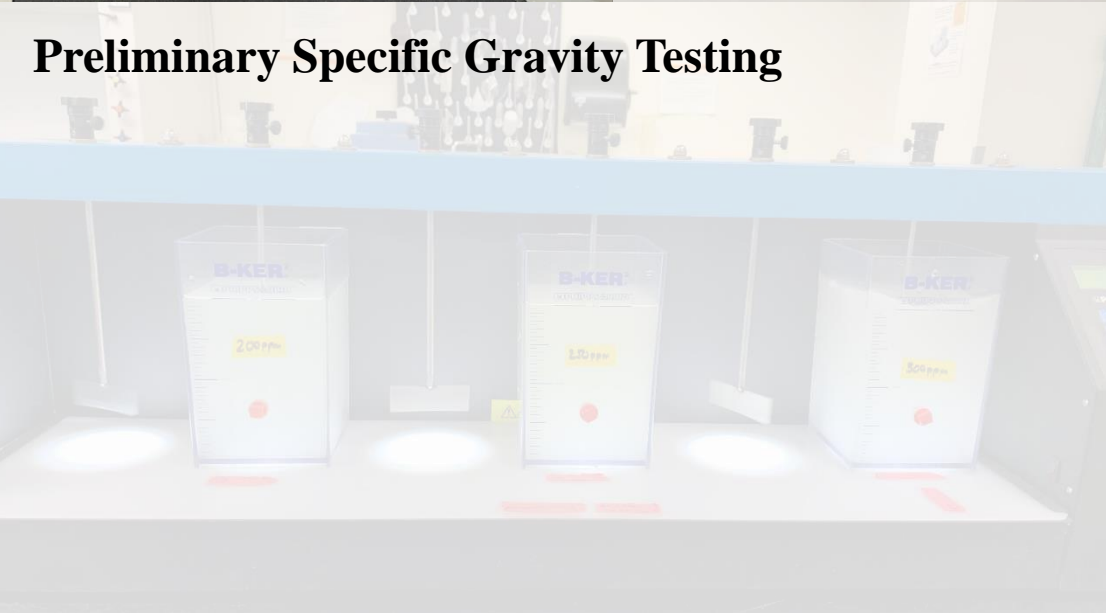
Testing



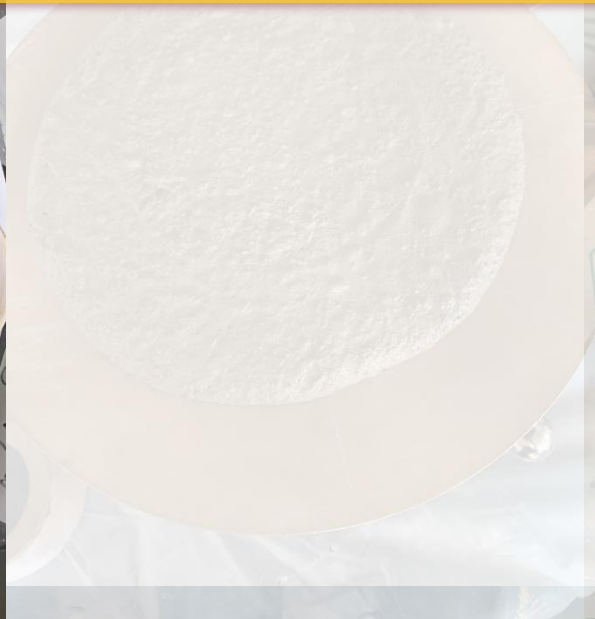
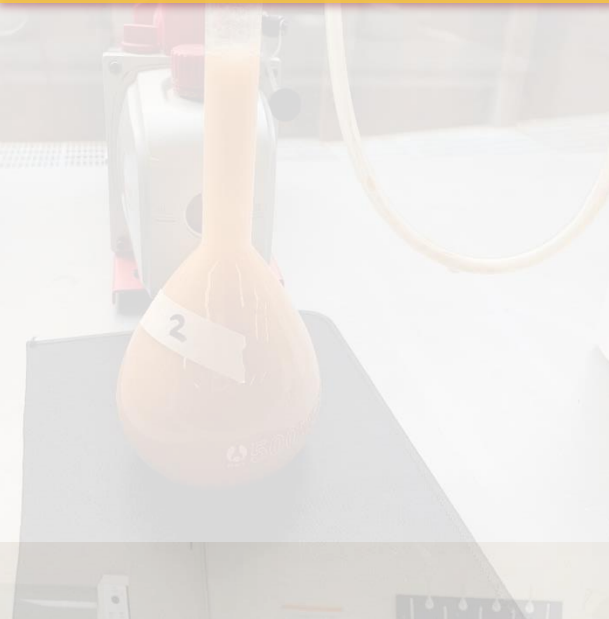
Material Characterization



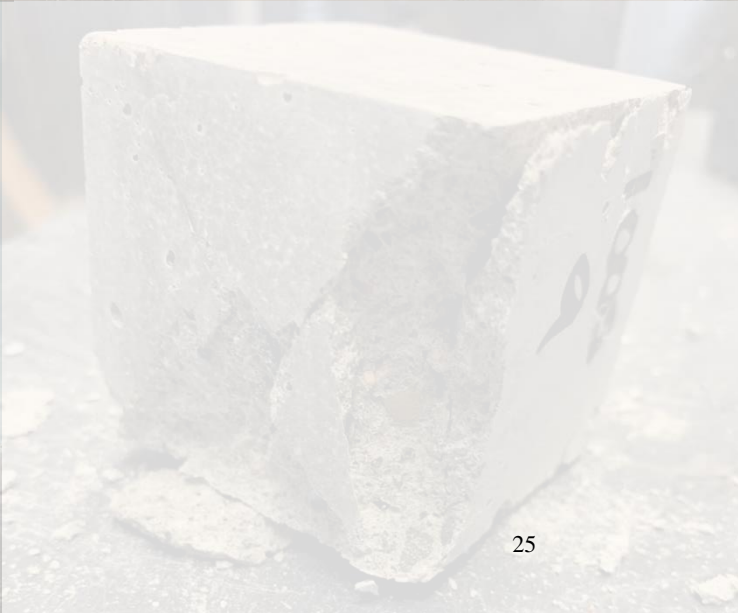
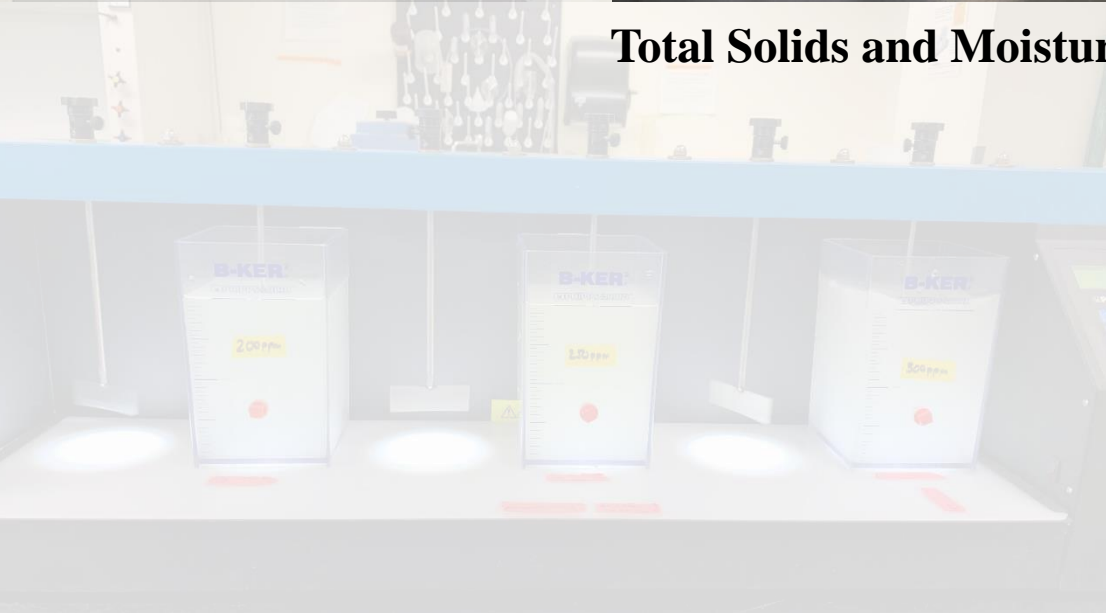
Preliminary Specific Gravity Testing



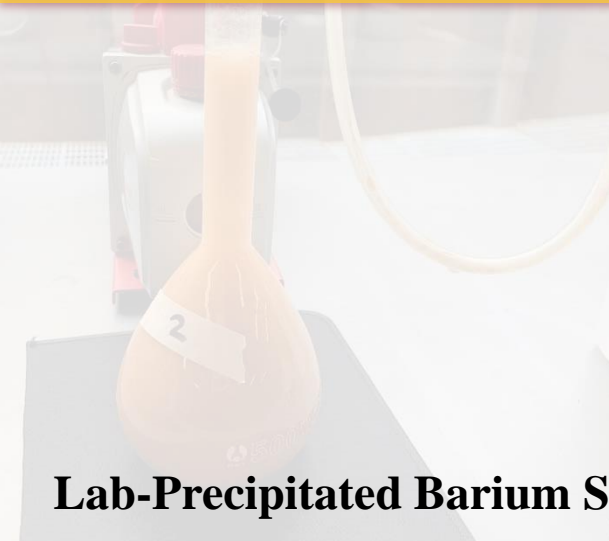
Material Characterization



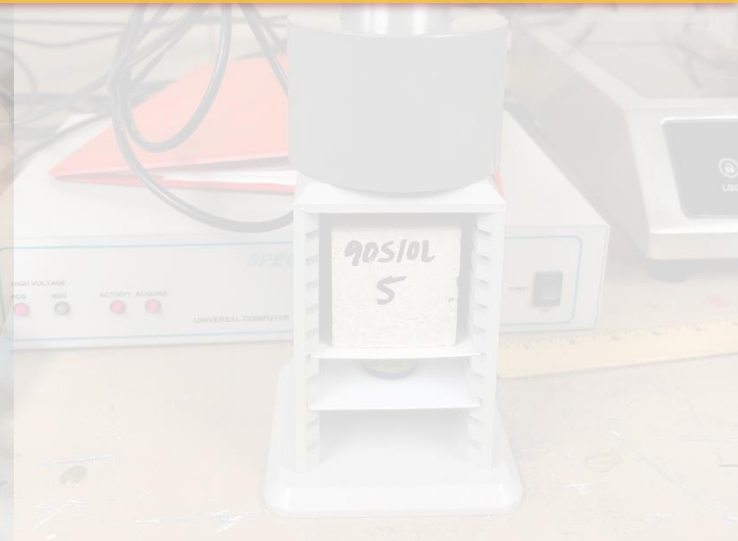
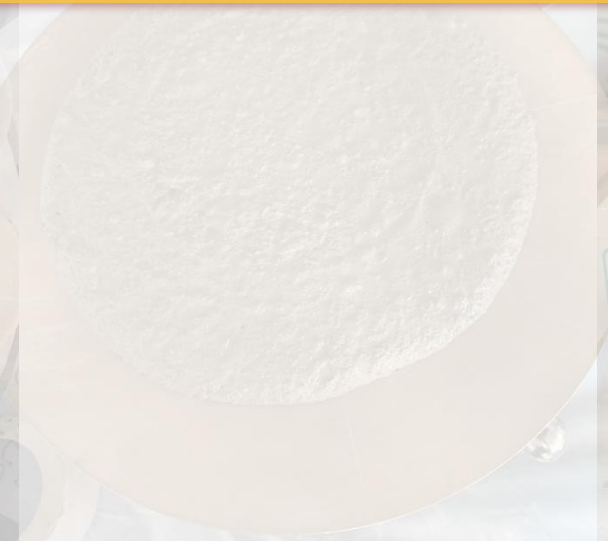
Total Solids and Moisture Content



Material Characterization



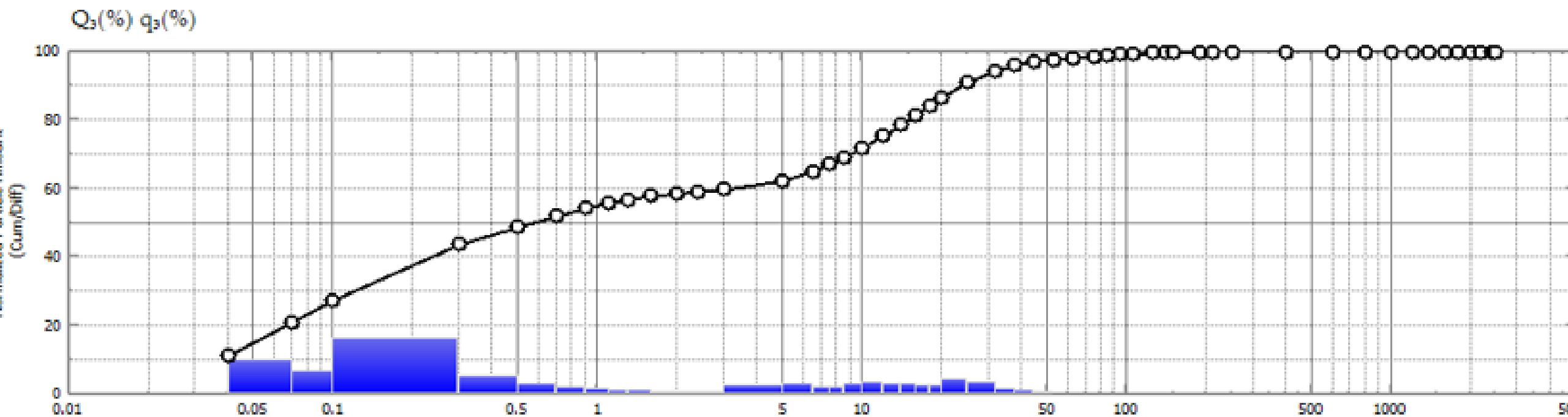
Lab-Precipitated Barium Sulfate



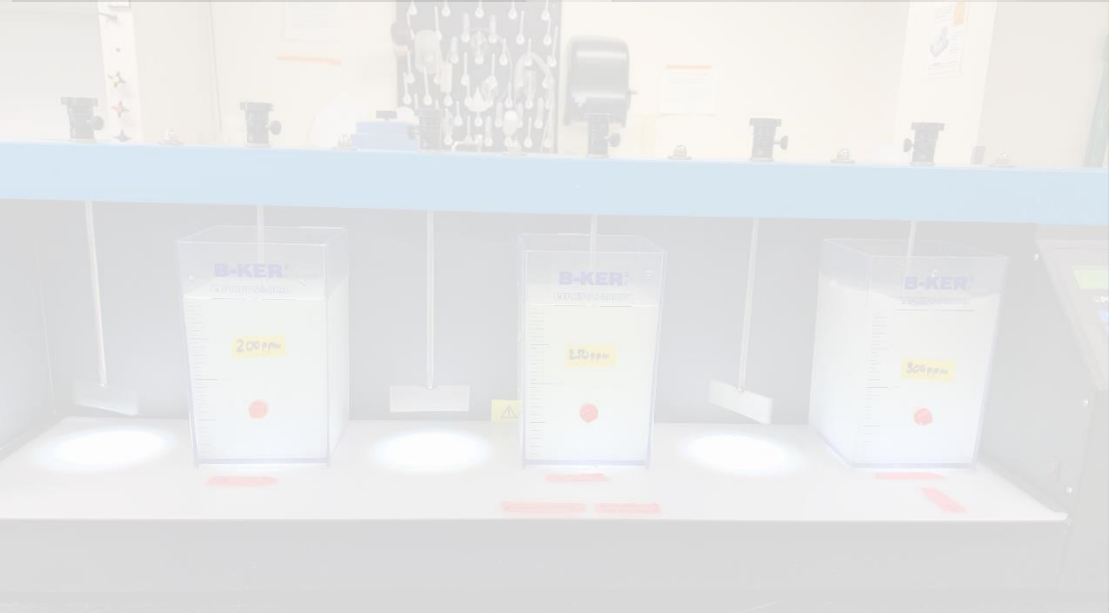
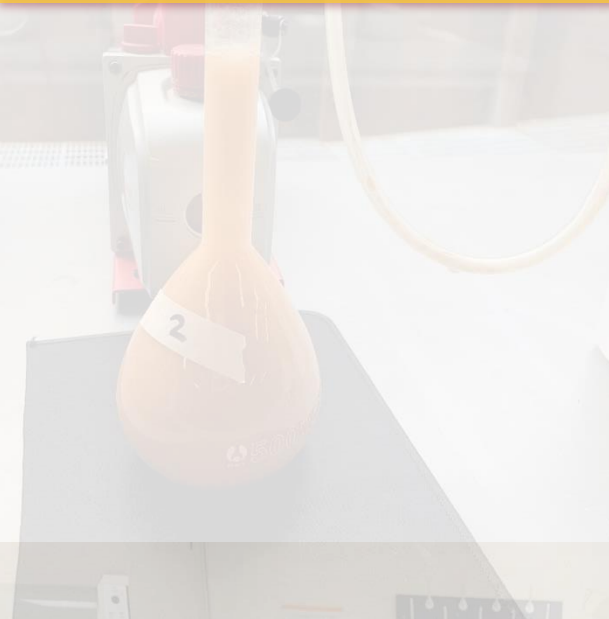
Material Characterization



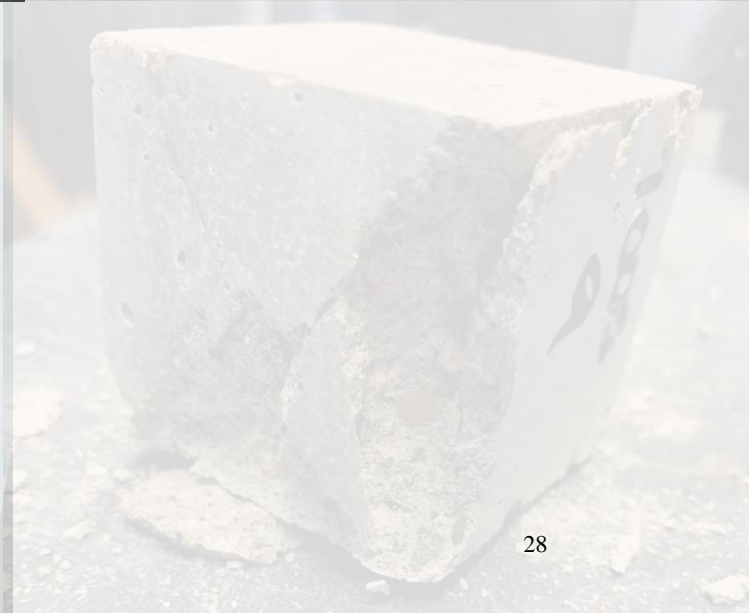
Particle Size Analysis



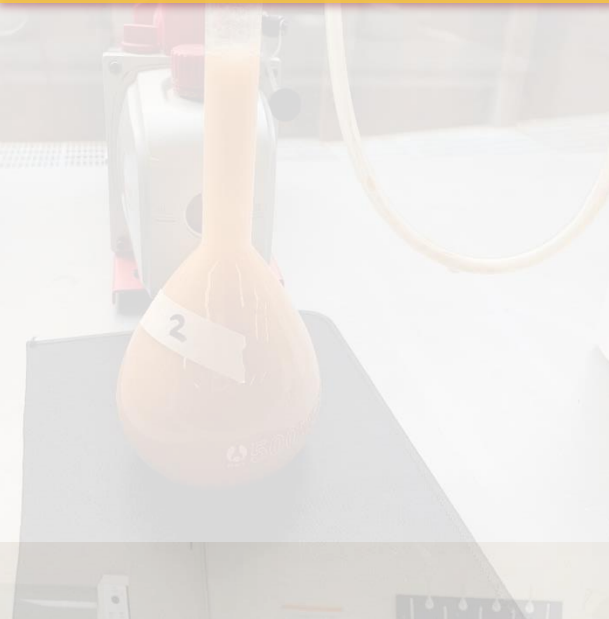
Material Characterization



Spread



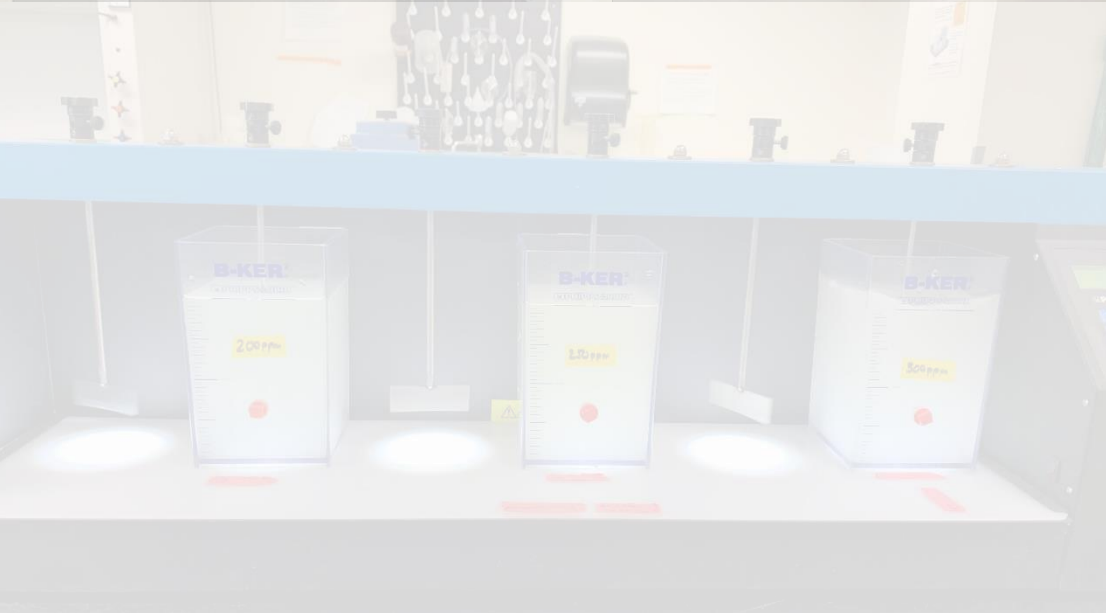
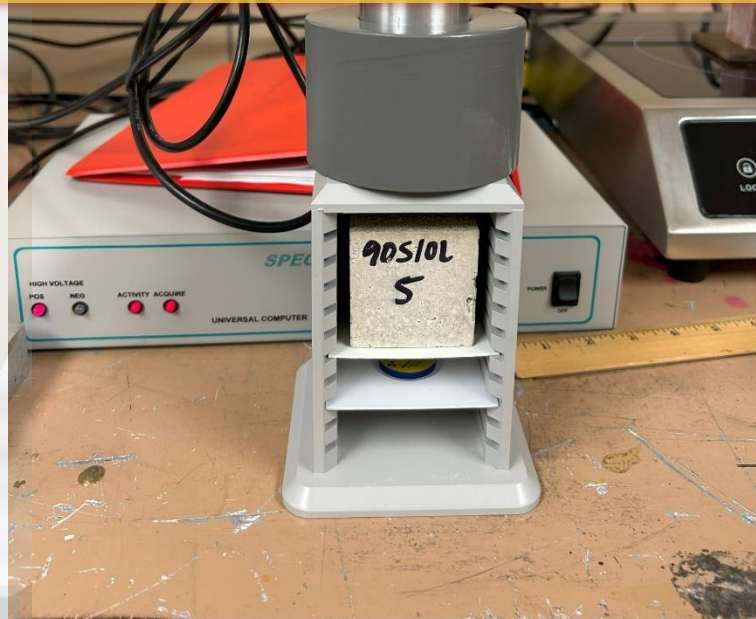
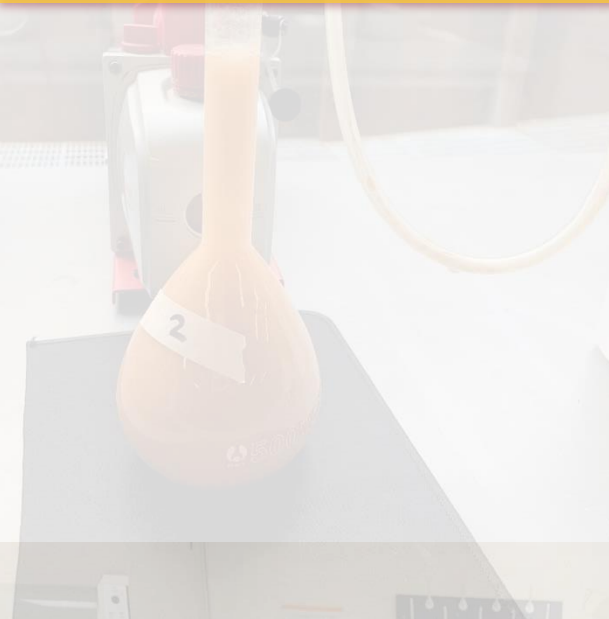
Material Characterization



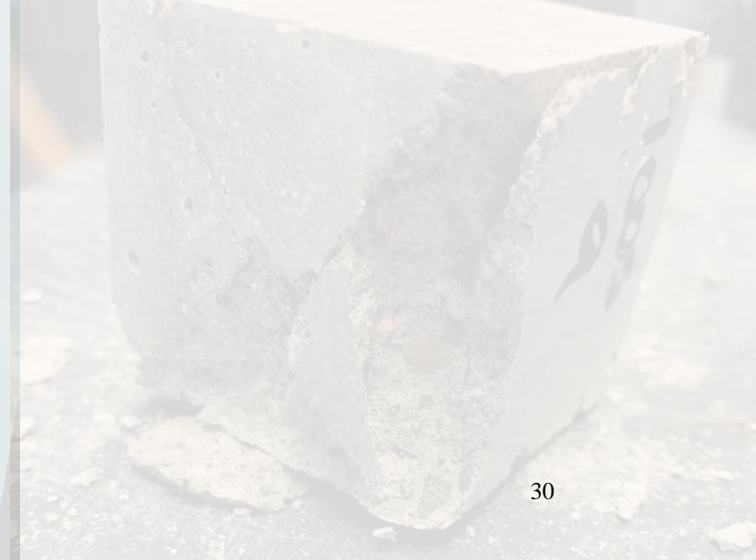
Compressive Strength



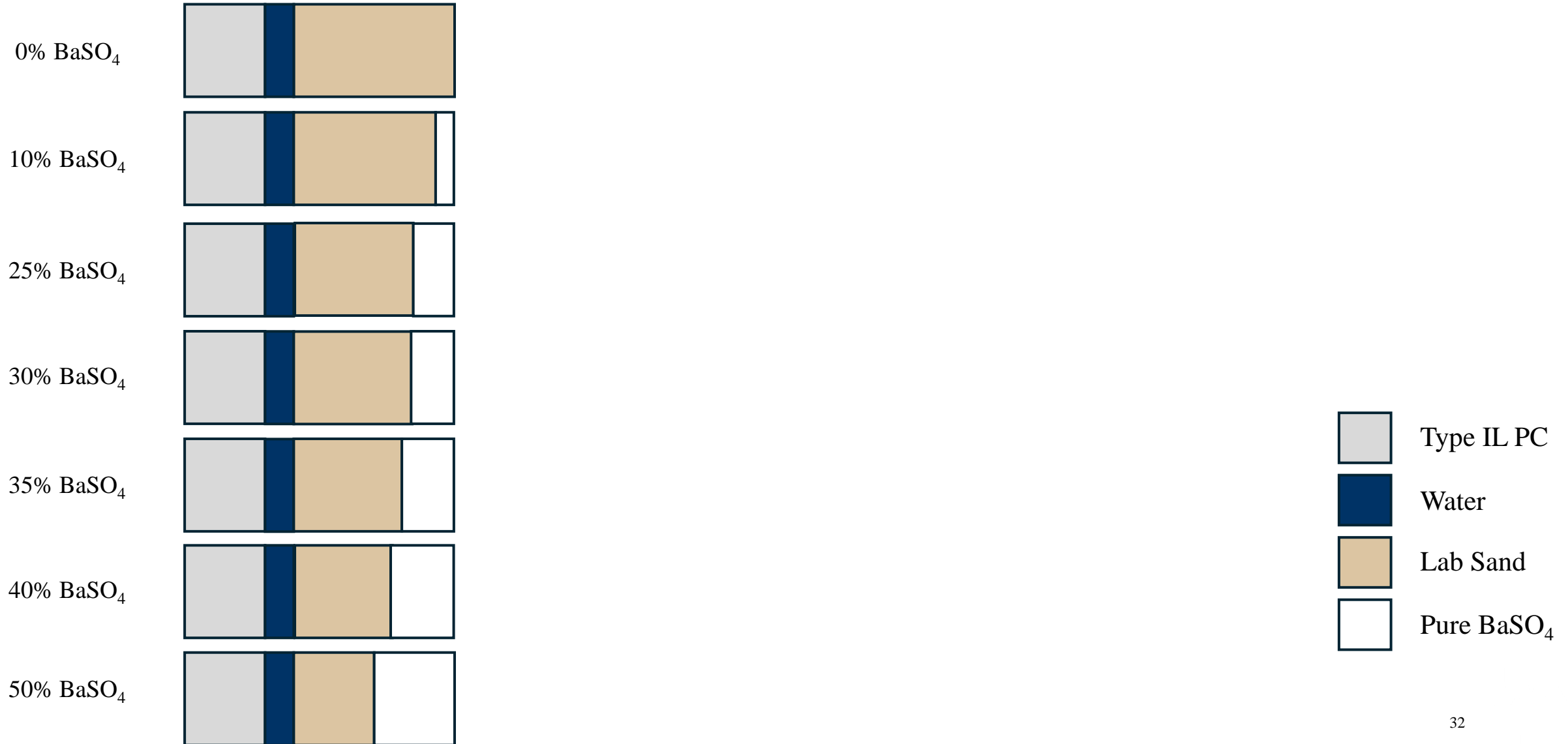
Material Characterization



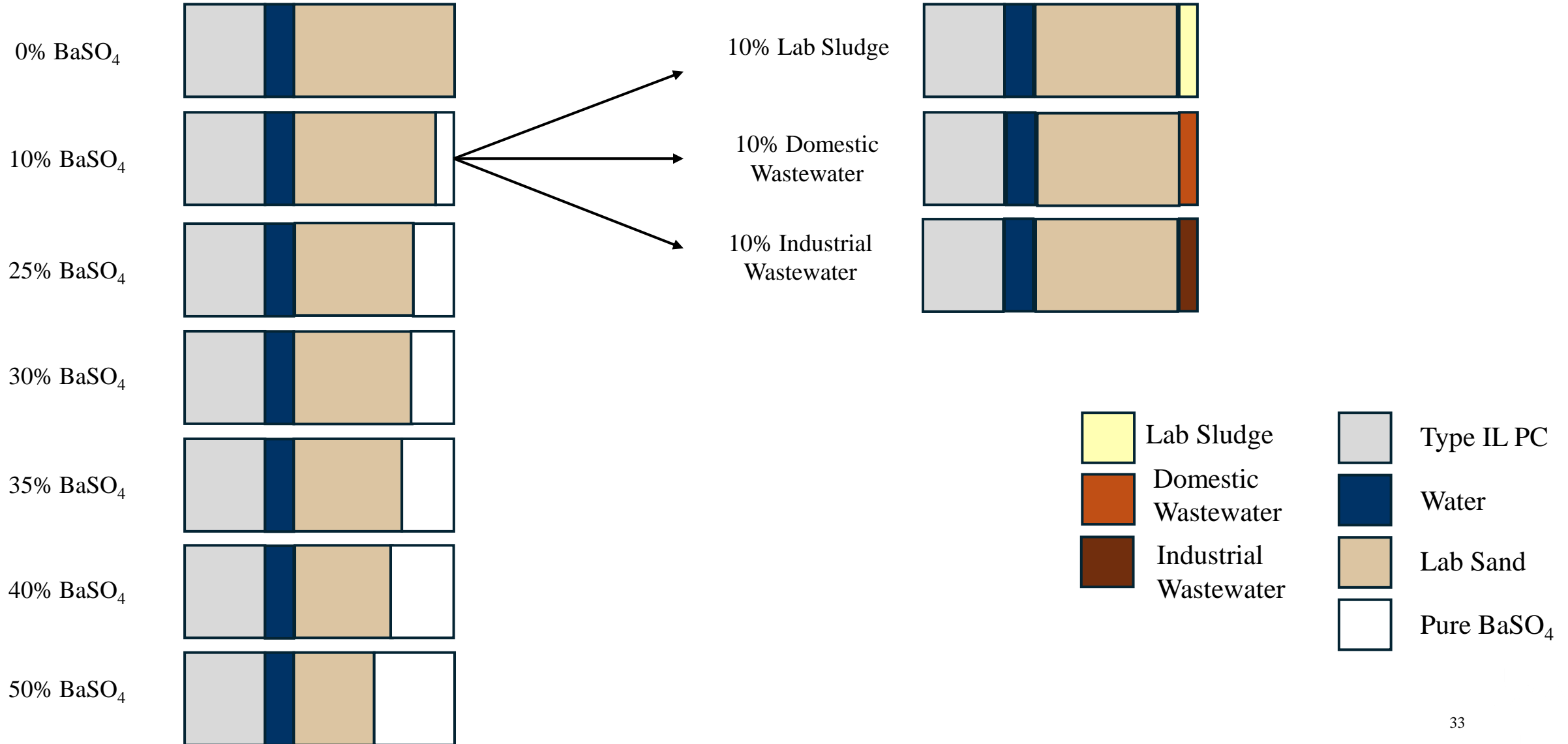
Radiation Attenuation



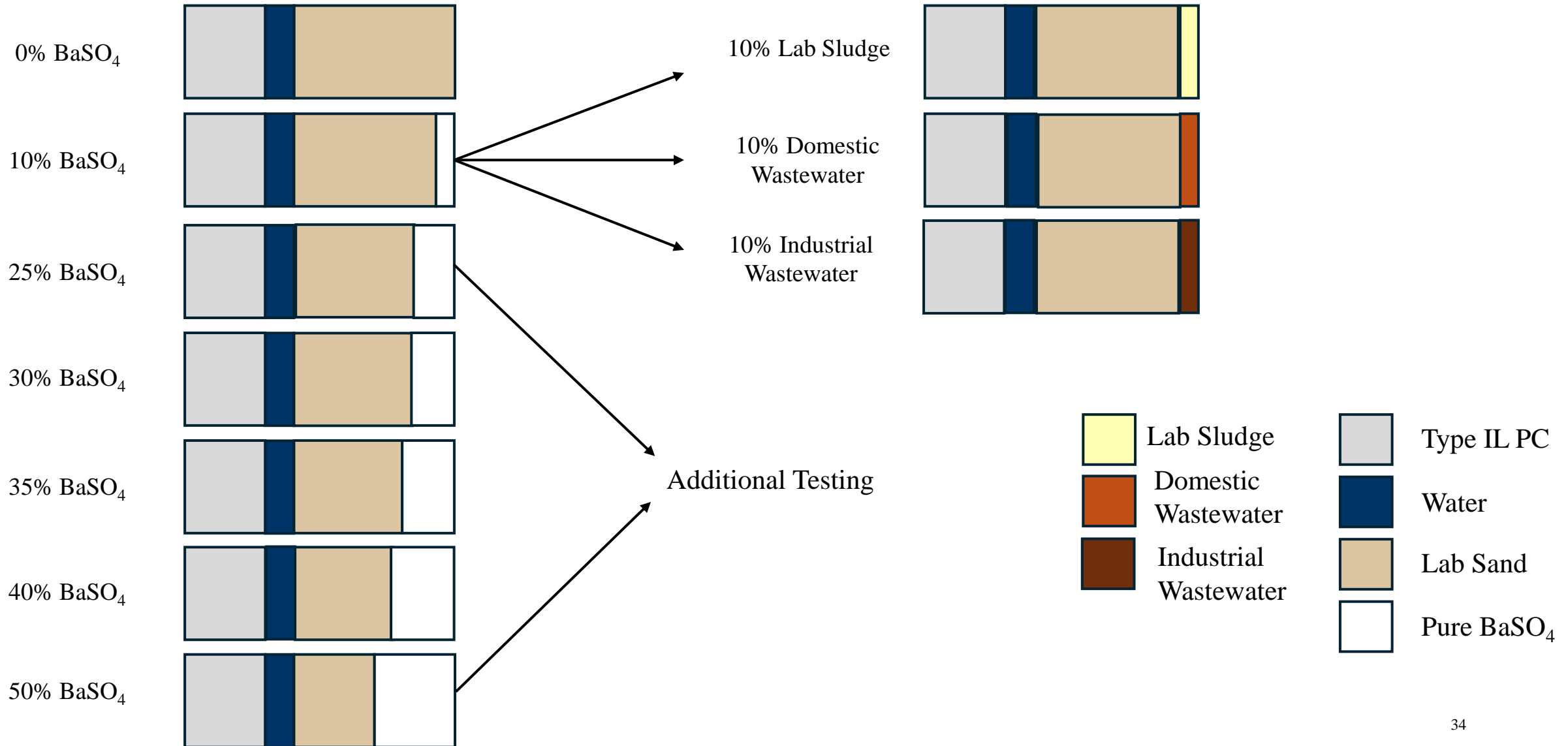
The Specimens – Aggregate Replacement by Mass



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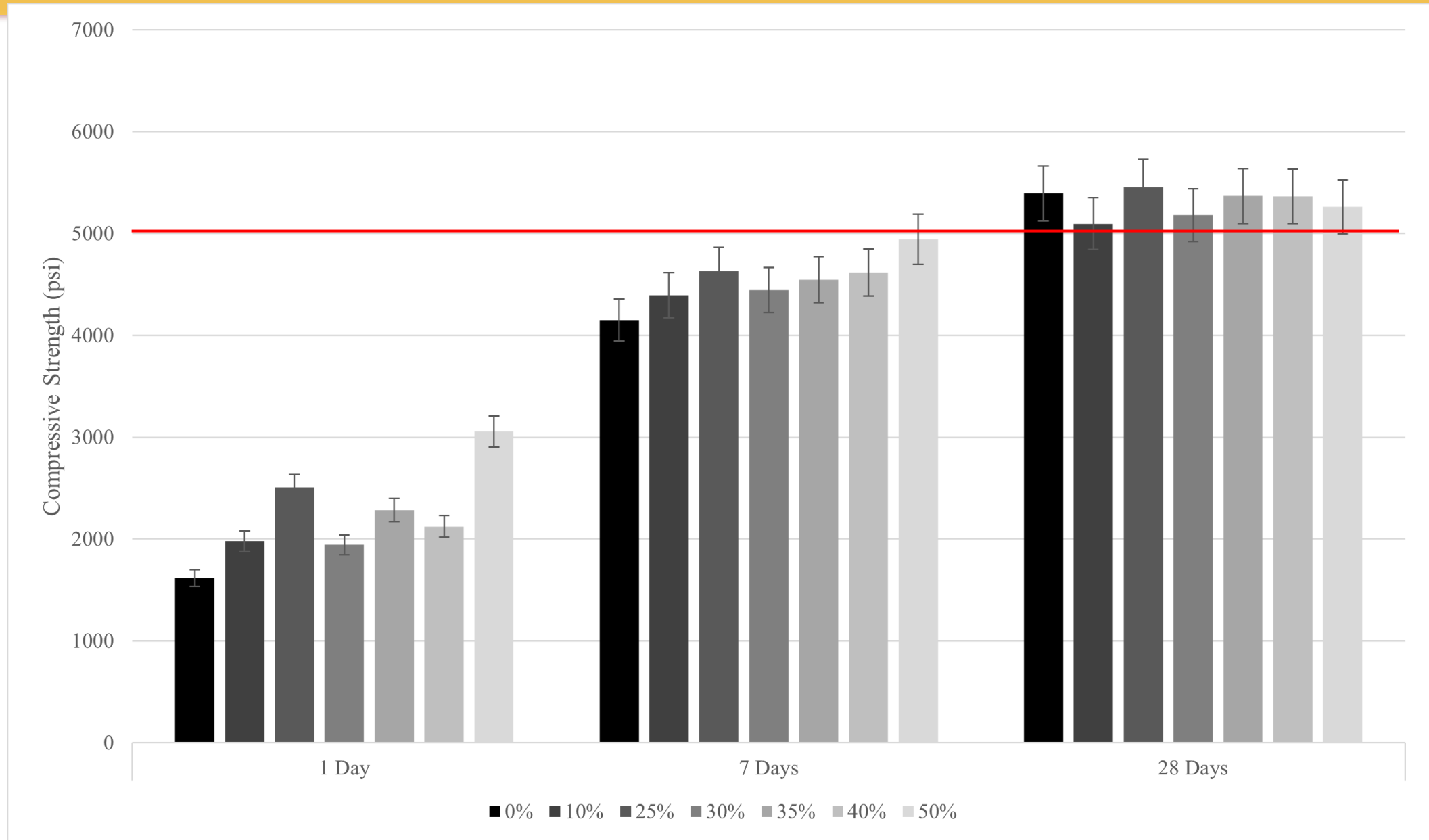


The Specimens – Aggregate Replacement by Mass

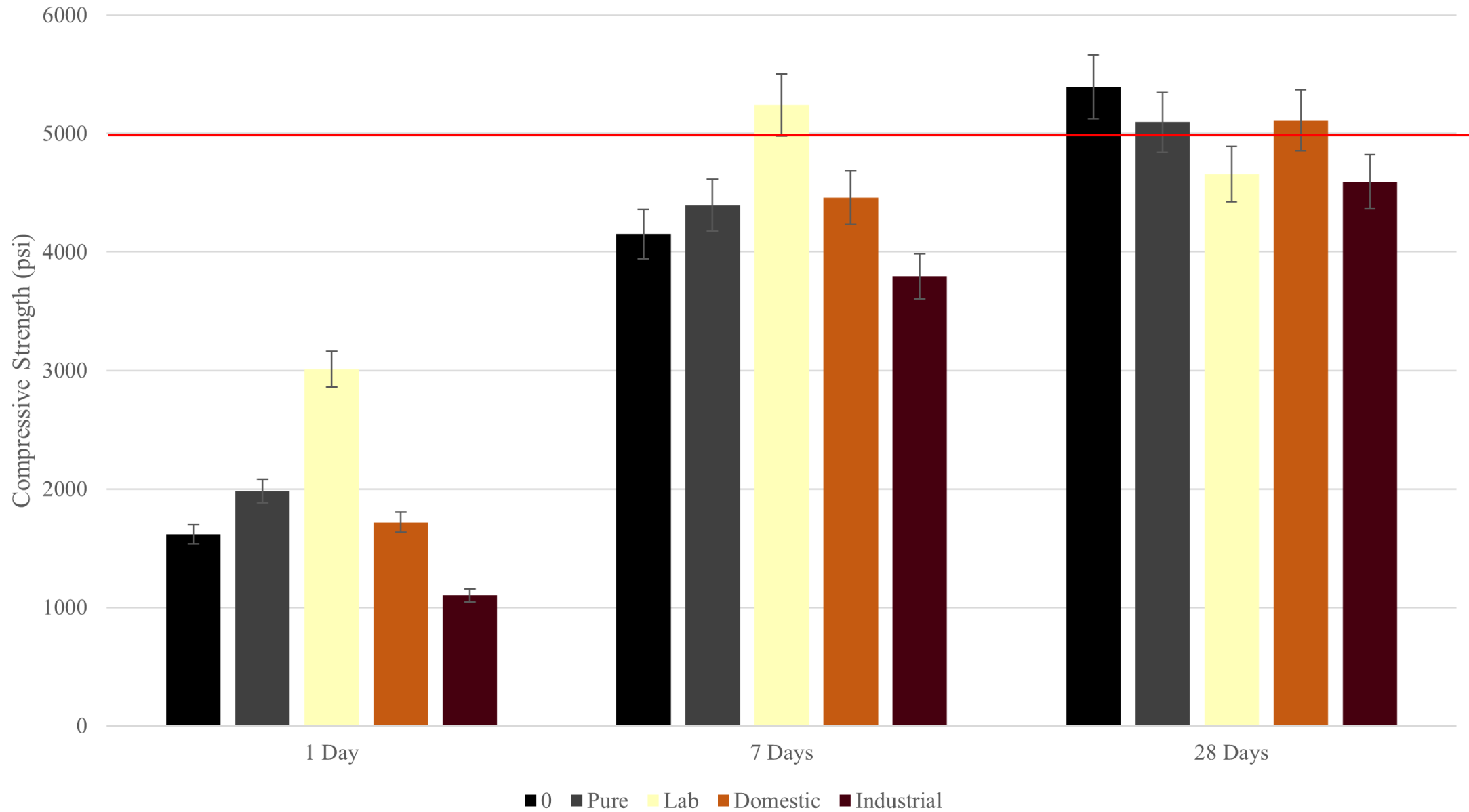


	Mix ID	Compressive Strength			Density	Attenuation								
		7 d	28 d	90 d		Cs137			Ba133			Co60		
						½"	1"	2"	½"	1"	2"	½"	1"	2"
0%	100S	X	X		X			X			X			X
Pure BaSO ₄	90S_10P	X	X		X			X			X			X
	75S_25P	X	X		X			X			X			X
	70S_30P	X	X		X									
	65S_35P	X	X		X									
	60S_40P	X	X		X									
	50S_50P	X	X		X									
Lab	90S_10L	X	X		X			X			X			X
Domestic	90S_10D	X	X		X			X			X			X
Industrial	90S_10I	X	X		X			X			X			X

Compression Testing



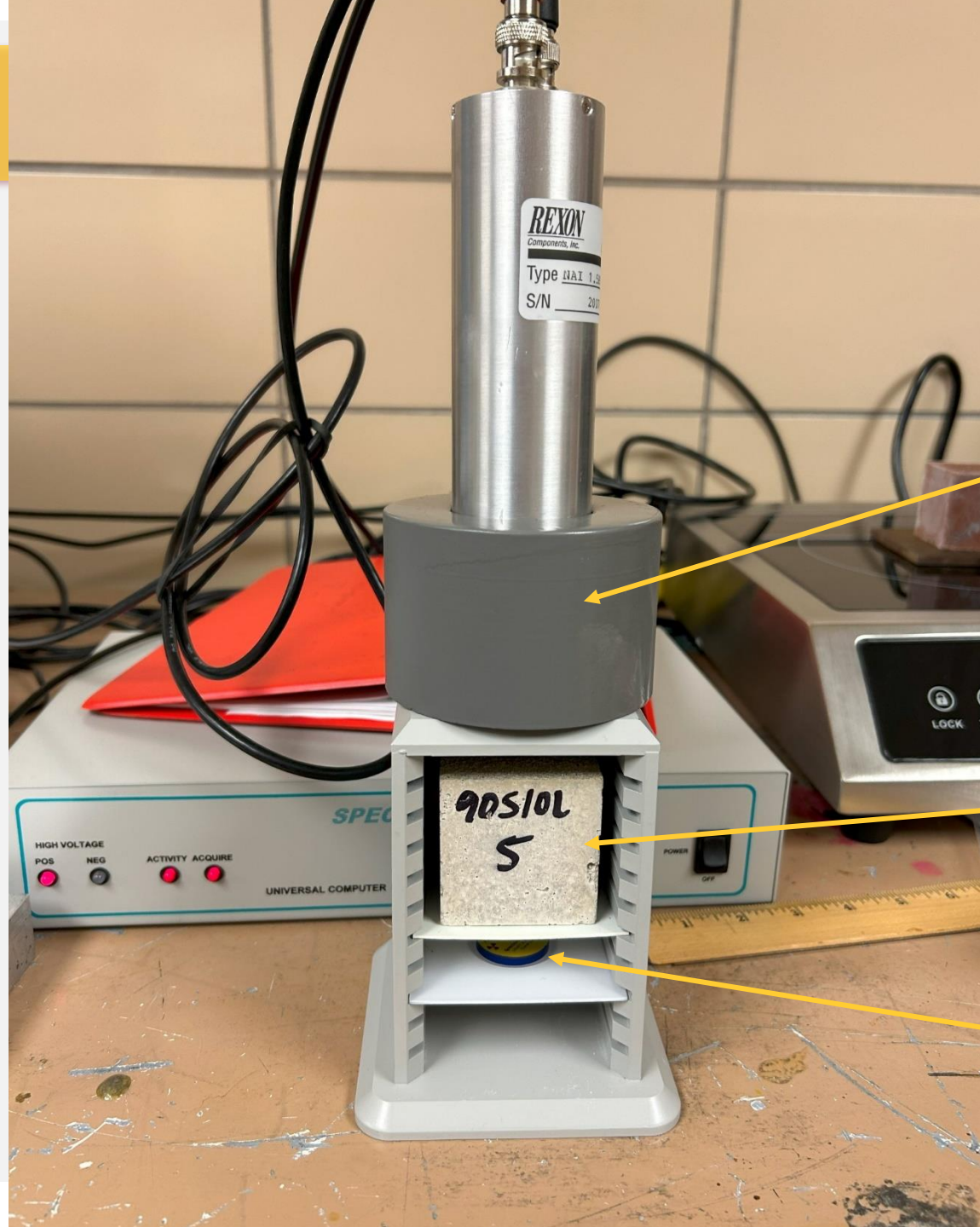
Compression Testing



Attenuation Testing

Attenuation Testing

Attenuation: the reduction of a force, effect, or value of something

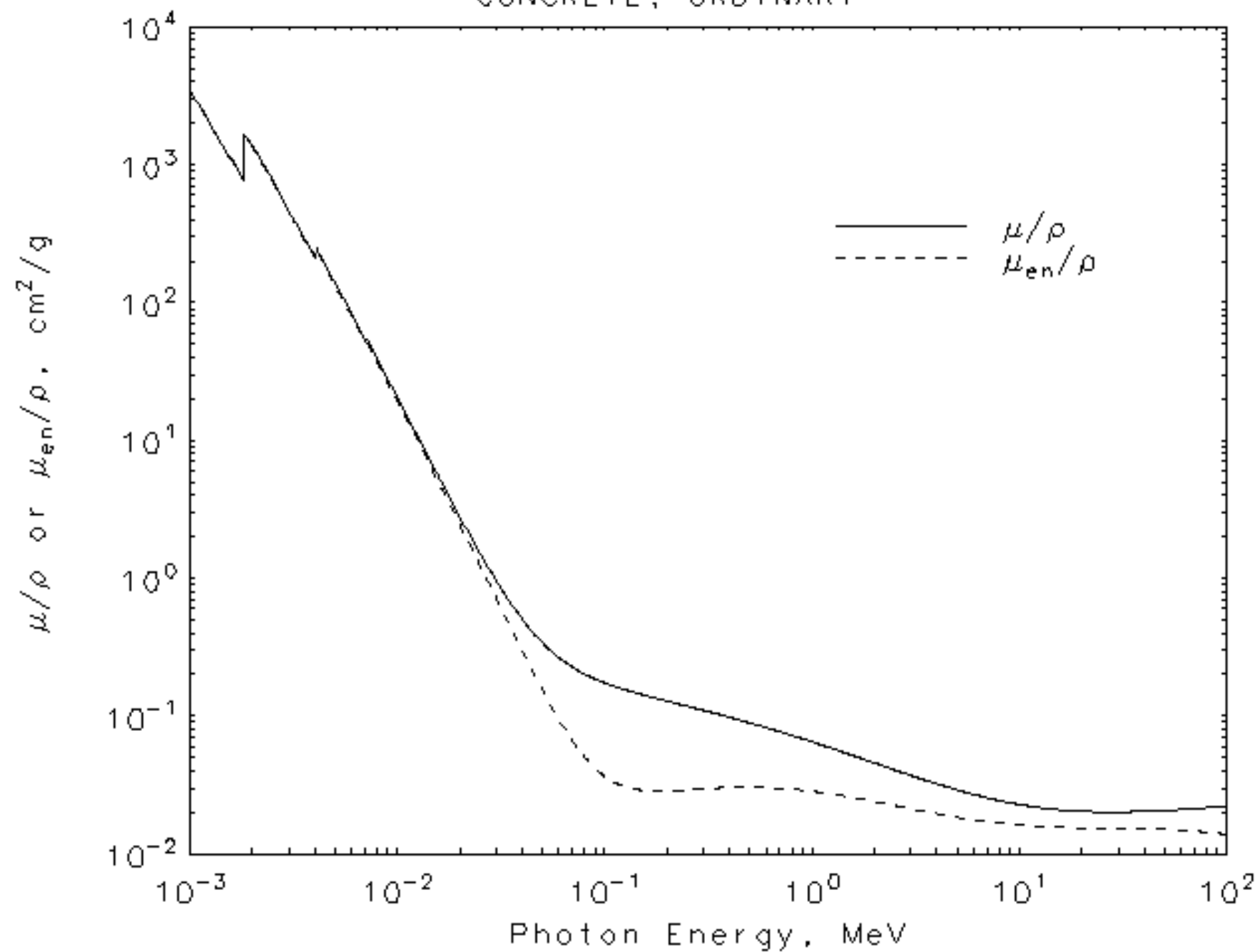


How much
radiation goes
through material

Material

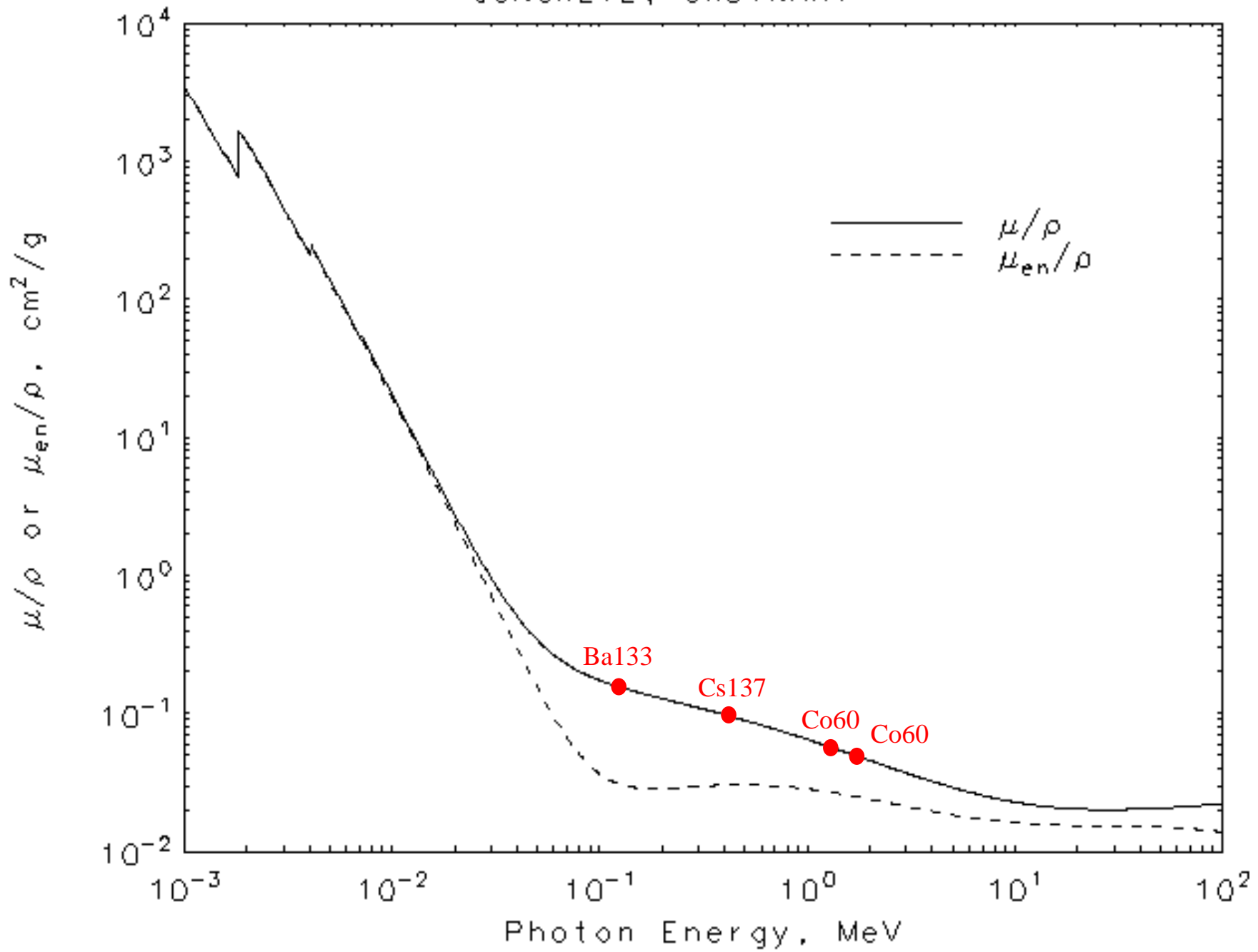
Radiation Source

CONCRETE, ORDINARY

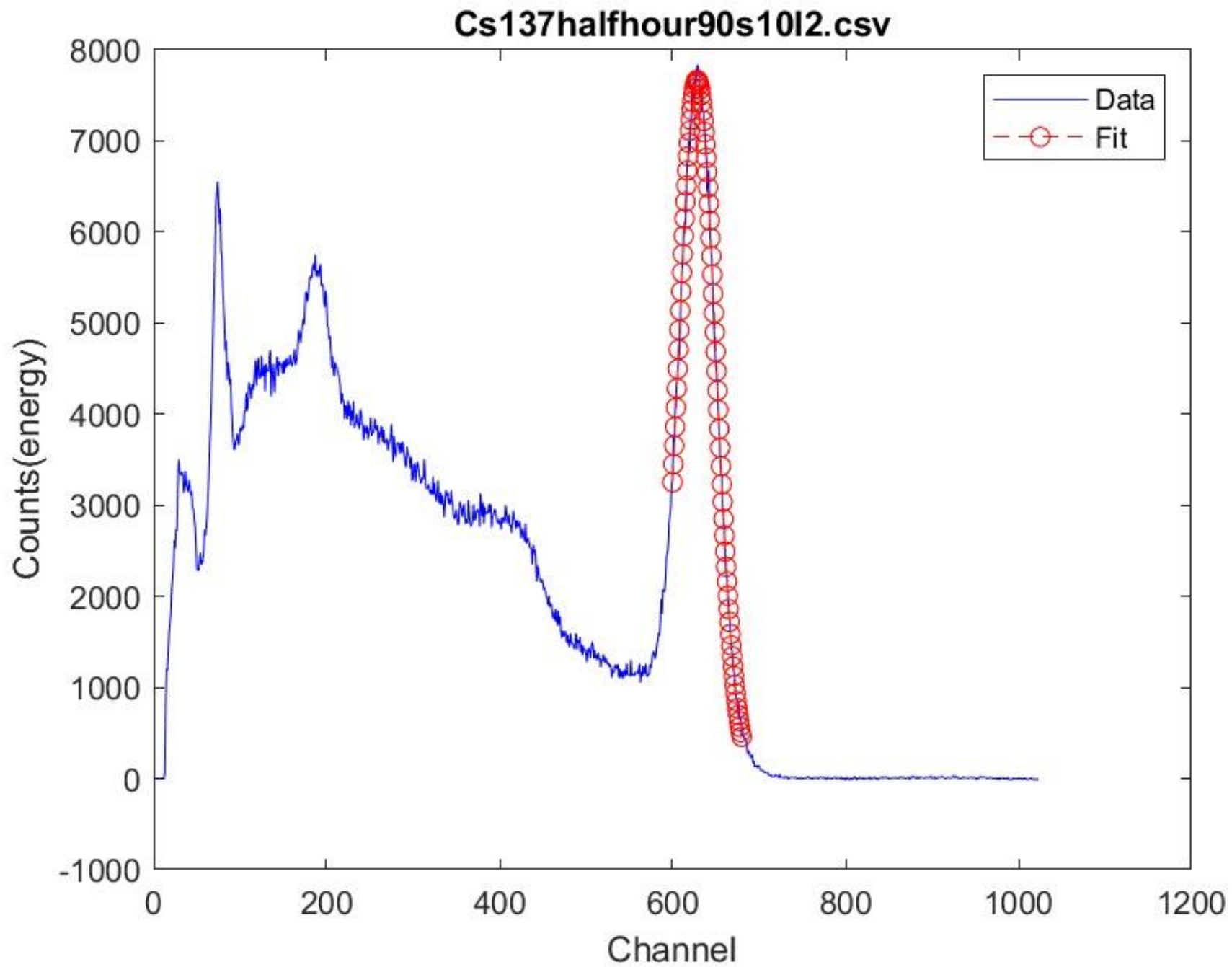


Rad

CONCRETE, ORDINARY

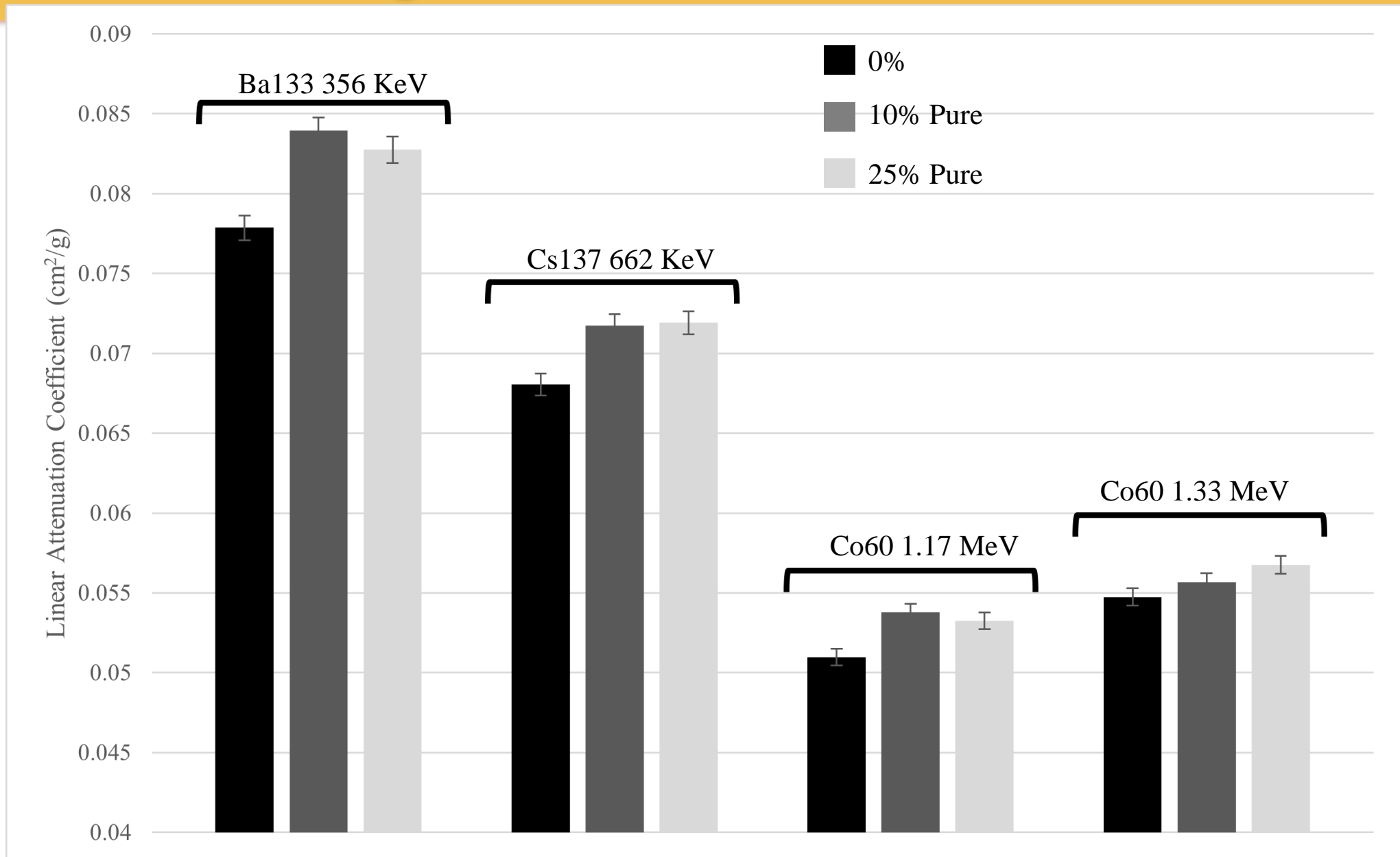


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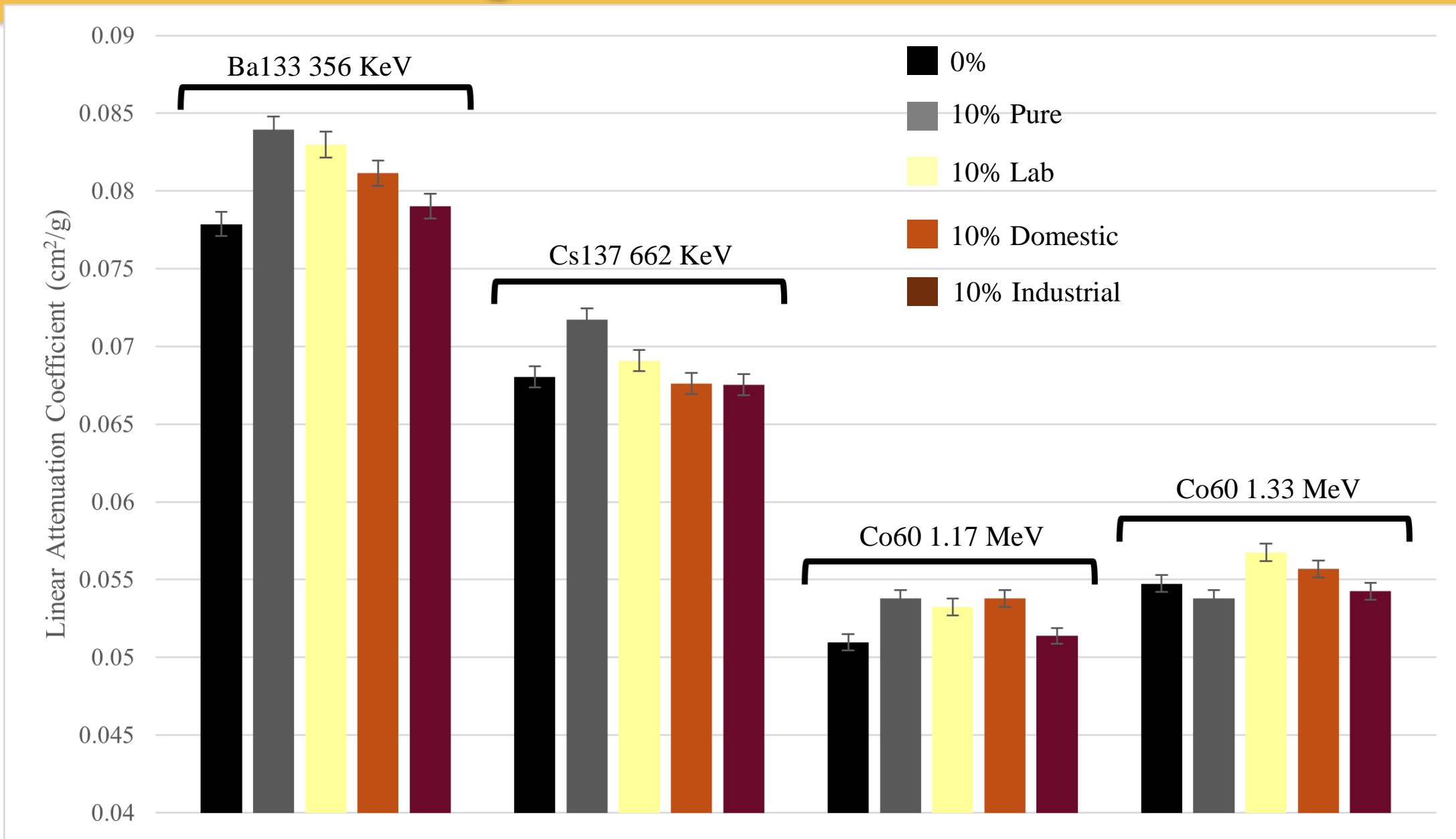


Rad

Attenuation Testing

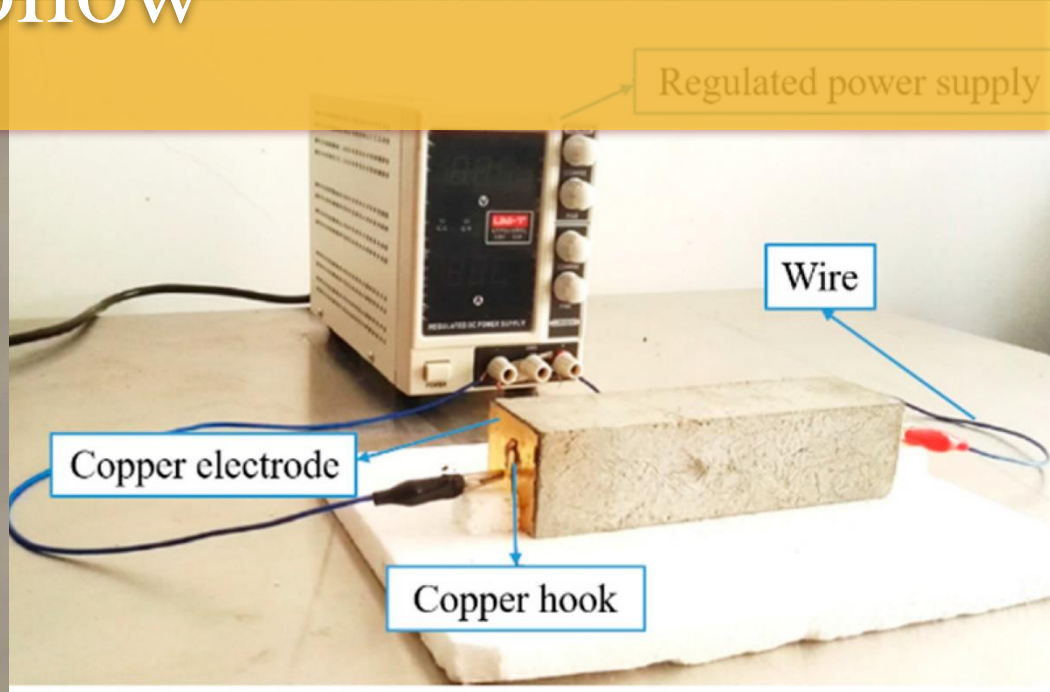


Attenuation Testing





More Testing to Follow



Thank You



Natural Resources
Research Institute

UNIVERSITY OF MINNESOTA DULUTH
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MINNESOTA POLLUTION
CONTROL AGENCY



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