Characterization of High pH Leachate Produced from Recycled Concrete Aggregate (RCA)

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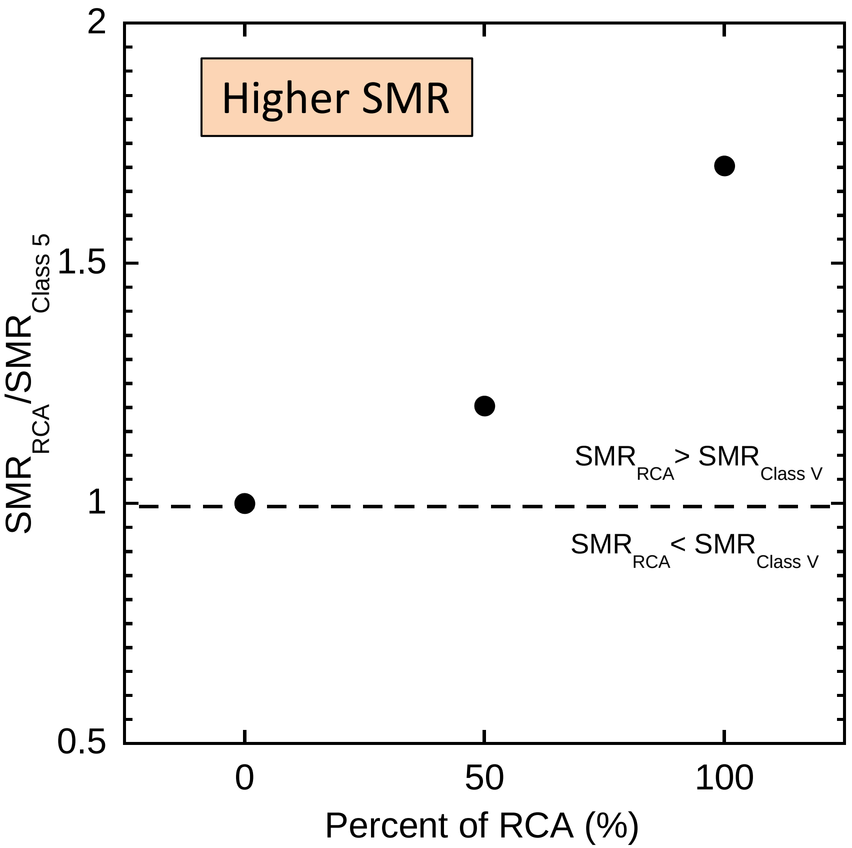
Background

- ☐ Recycled Concrete Aggregate (RCA)
  - Demolition of concrete pavement, bridge structures, roadway structures, airport runways
- ☐ Uses
  - Infrastructure backfill; e.g., pavement base course

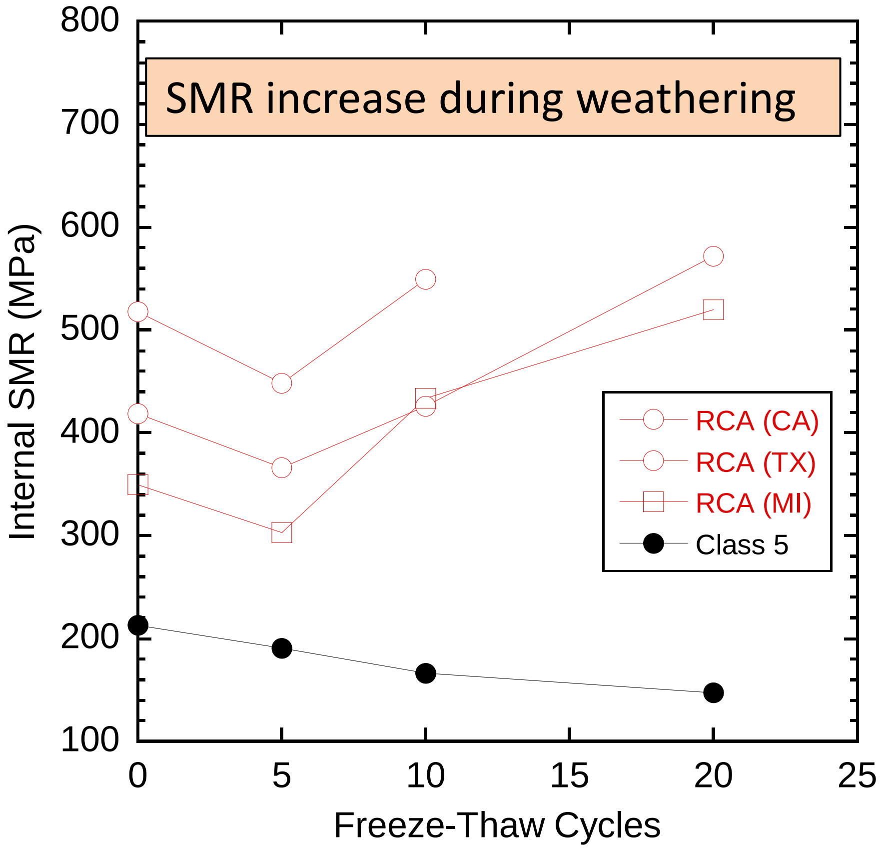
http://www.oregrinder.com/

Advantages

- Advantages
  - Excellent mechanical properties



Higher SMR

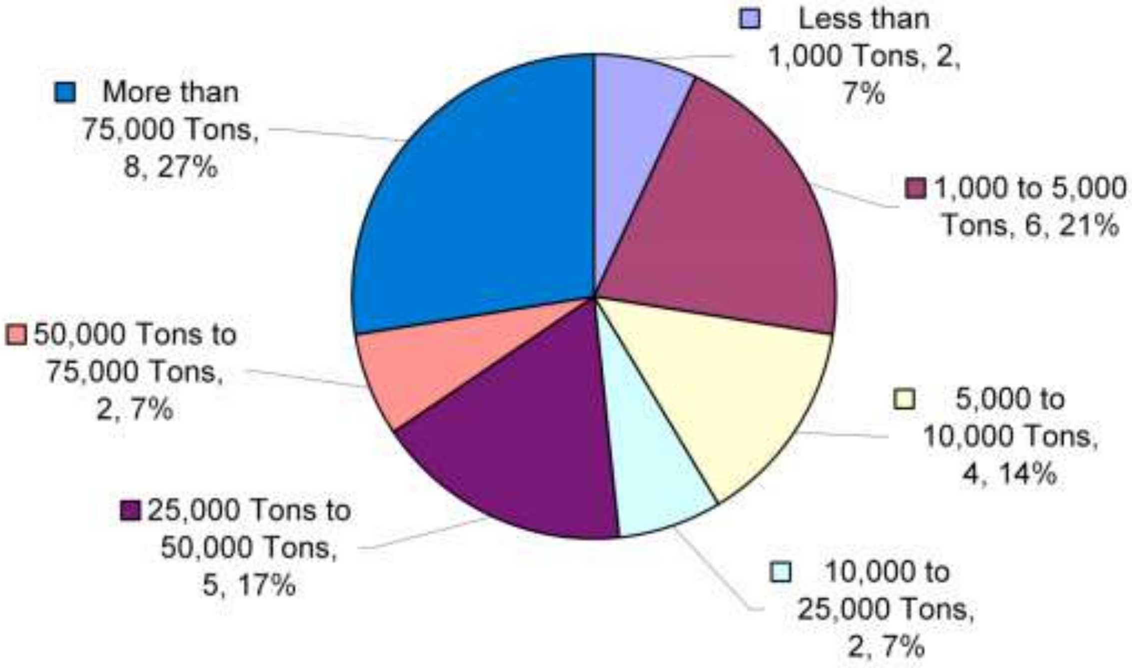


SMR increase during weathering

SMR = Summary Resilient modulus , Class 5 = Natural aggregate Edil et al. (2012)

Advantages (cont'd)

❑ Resource conservation – RCA Widely available



Edil et al. (2012)

- Survey based on 34 state and federal transportation agencies
- An average of 140 million tons of RCA is produced annually
- 27% of the respondents used more than 75,000 tons

High pH Leachate from RCA

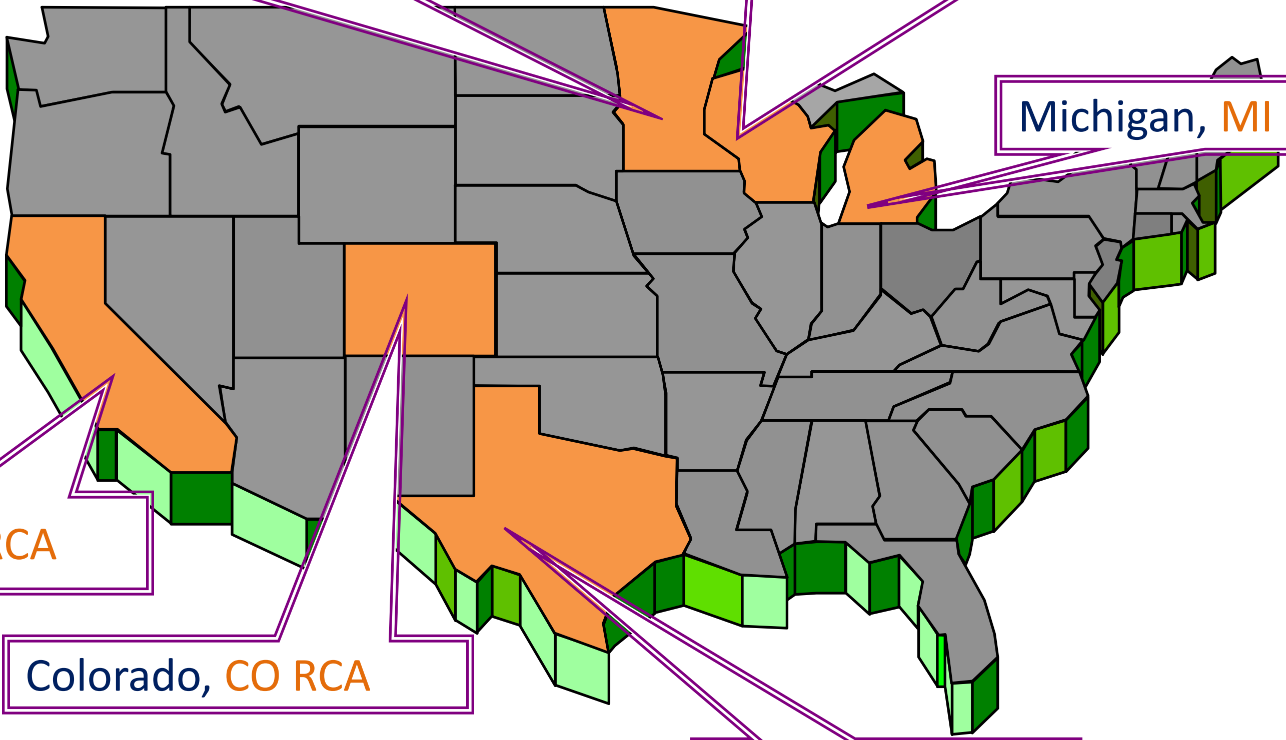
- ☐ High Alkaline Leachate
  - Cement-based material (potlandite, lime, brucite, etc)
  - Washington state pH limit of discharges to groundwater 6.5 to 8.5
- ☐ Leaching of hazardous elements
  - pH-dependent leaching (Chen et al. 2012)
  - As and Cr more soluble at high pH (> 10)

From Iowa DOT (1999)

Previous Research Work by the University of Wisconsin - Madison

- Hazardous elements and pH of leachates from RCAs in field and lab tests
  - Field lysimeter sampling at two locations
  - Lab column leaching tests

Materials - RCA



Minnesota, MN RCA, Class V

Wisconsin, WR- F and WR-SP RCA, AW

Michigan, MI RCA

California, CA RCA

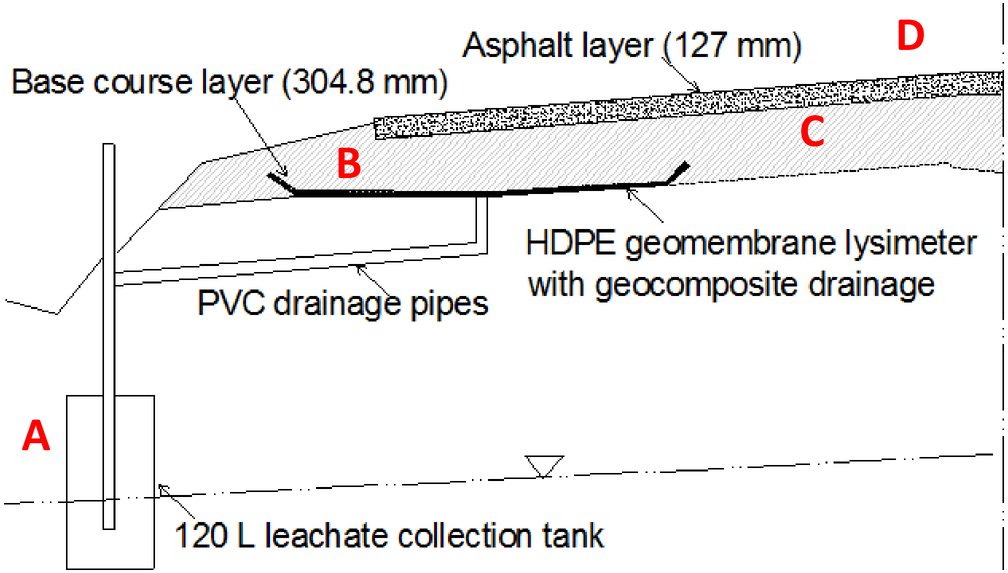
Colorado, CO RCA

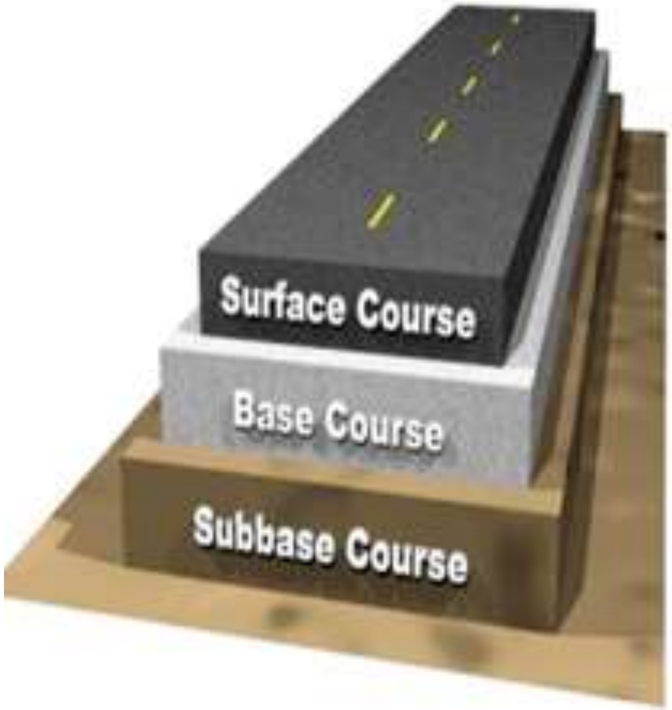
Texas, TX RCA

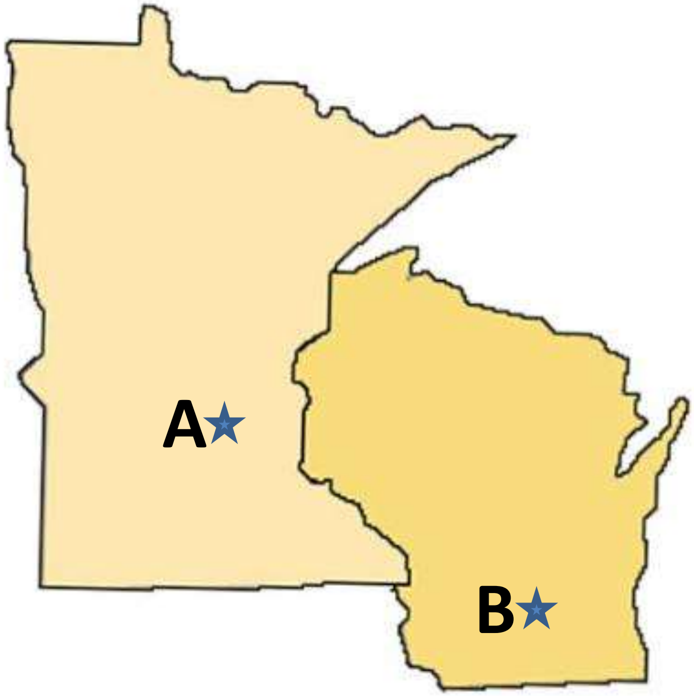
- CA, CO, MI, MN and TX RCA samples were provided by pooled fund project member states.

Field Leaching Tests

- Lysimeters





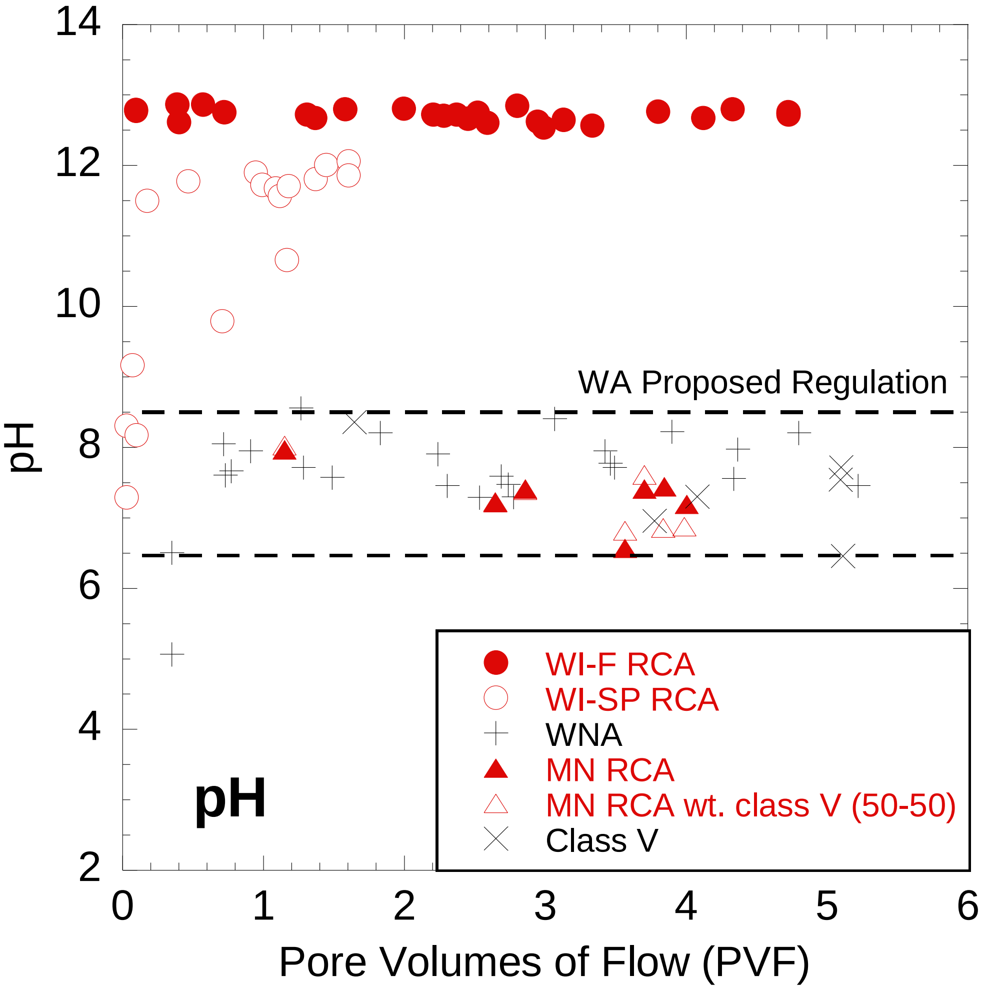


Source: Google map

- ***From Sep. 2008 to present***
- Cell 16: MN RCA
- Cell 17: MN RCA – Class 5 (50/50)
- Cell 19: Class 5

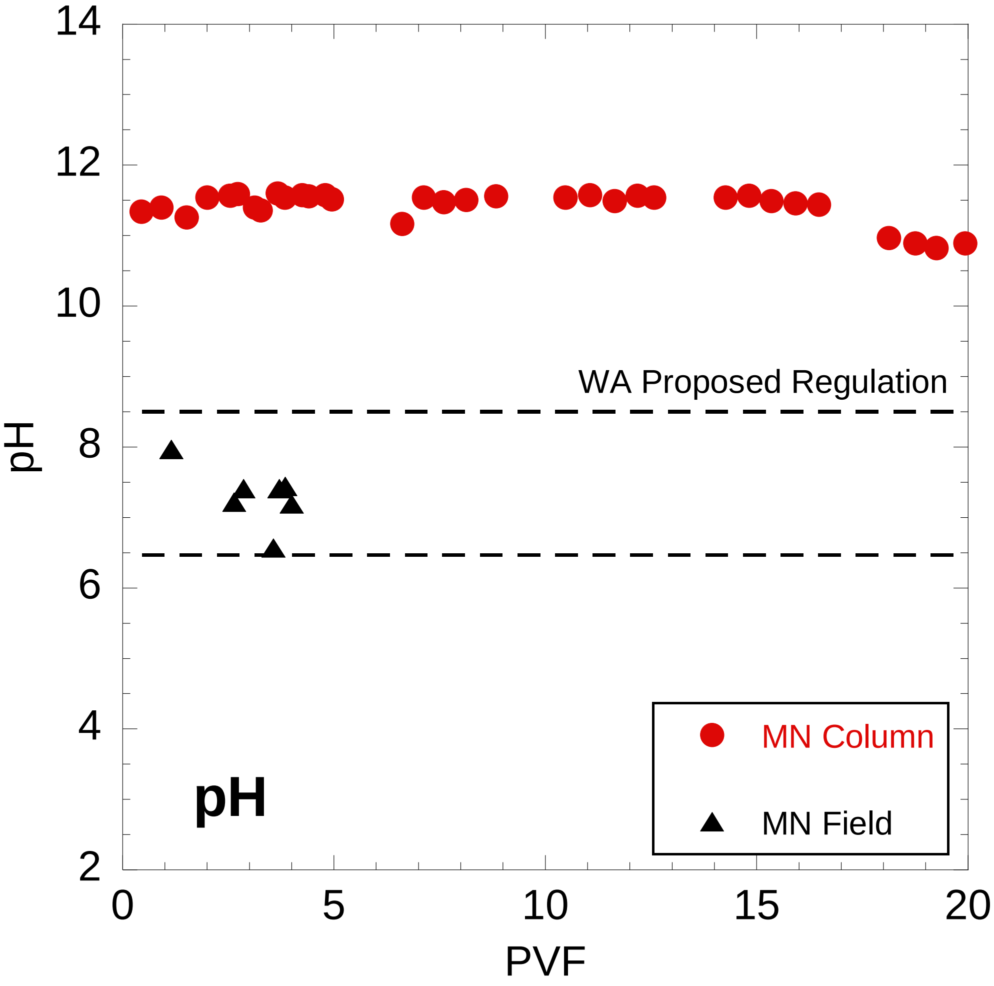
- ***From Sep. 2011 to 2013***
- Cell 1: WR-F RCA (fresh)
- Cell 2: WR-SP RCA (stock piled-aged))
- Cell 3: AW (Dolomite Aggregate)

pH of Leachate from MnRoad and UW Field Sites



- pH from **field** leaching tests within **6.5 ~ 12.6.**
- MN RCA had ***low pH (~ 7)*** effluent from field base course application
- WR RCAs had ***high pH (> 11)*** effluent from field parking lot base course application
- Literature: pH from RCA range from 7.5 to 13.

pH of Leachate from Field and Lab Leaching Tests



- RCA from MnRoad
- pH from field leaching within ***6.5 ~ 8.0***.
- pH from column leaching tests within ***11.3 ~ 11.6***.
- Similar observation was found by Roque et al. 2016.

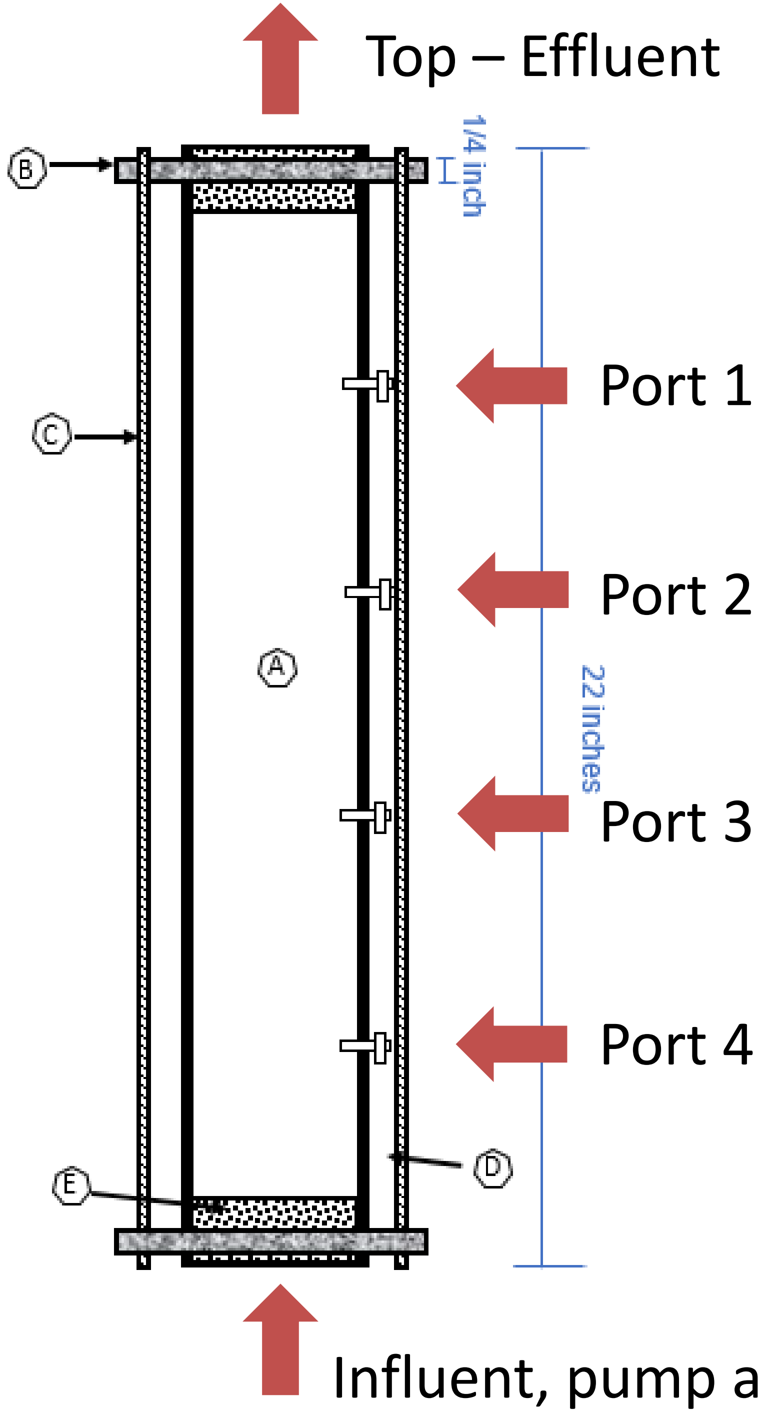
Current Work in University of Wisconsin - Madison

☐ Buffering capacity of subgrade soil to high pH

☐ Exploring the way for pH control on RCA - how to meet WA state pH regulation of discharges to groundwater (<pH = 8.5)

☐ Examine the reason for low pH in MnRoad field site (August, 2016 forensic study)

Column Tests Setup



Top – Effluent

Port 1

Port 2

Port 3

Port 4

Influent, pump at 1 PVF per day

Influent Chemistry

pH	12.6	
Ionic Strength	0.28	M
Alkalinity	0.23	M

*Prepared by NaOH and $NaHCO_3$, add 20 ppm LiBr as tracer

Column Packing – Subgrade Soils

Table 1. Characteristics of clay liner soils used in this study.

Soil ID	USCS Group Symbol	USCS Group Name	Origin	Compaction (ASTM D 698)	
				w_{opt} (%)	γ_{dmax} (kN/m^3)
SC-10	SC	clayey sand	Monterey, CA	13.4	18.6
M-14	MH	elastic silt	Atlanta, GA	22.5	15.5
CL-25	CL	lean clay	Omaha, NE	19.6	16.4
CH-38	CH	fat clay	Denver, CO	24.1	15.4

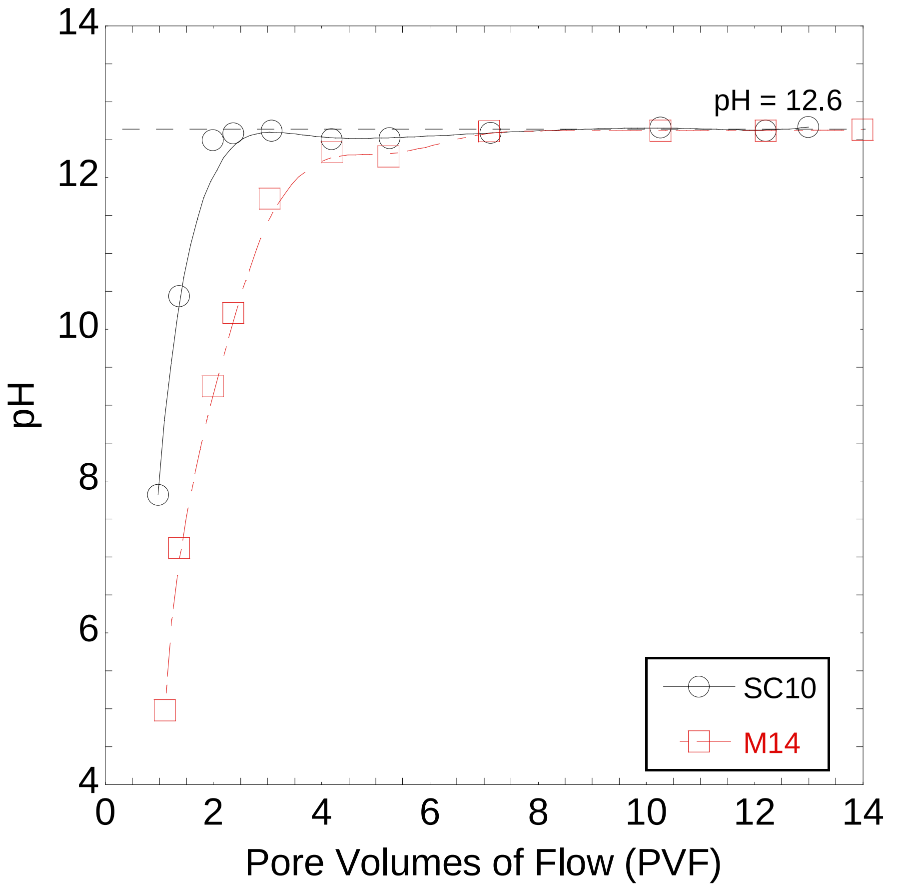
Table 2. Atterberg limits and particle size fractions of clay liner soils used in study.

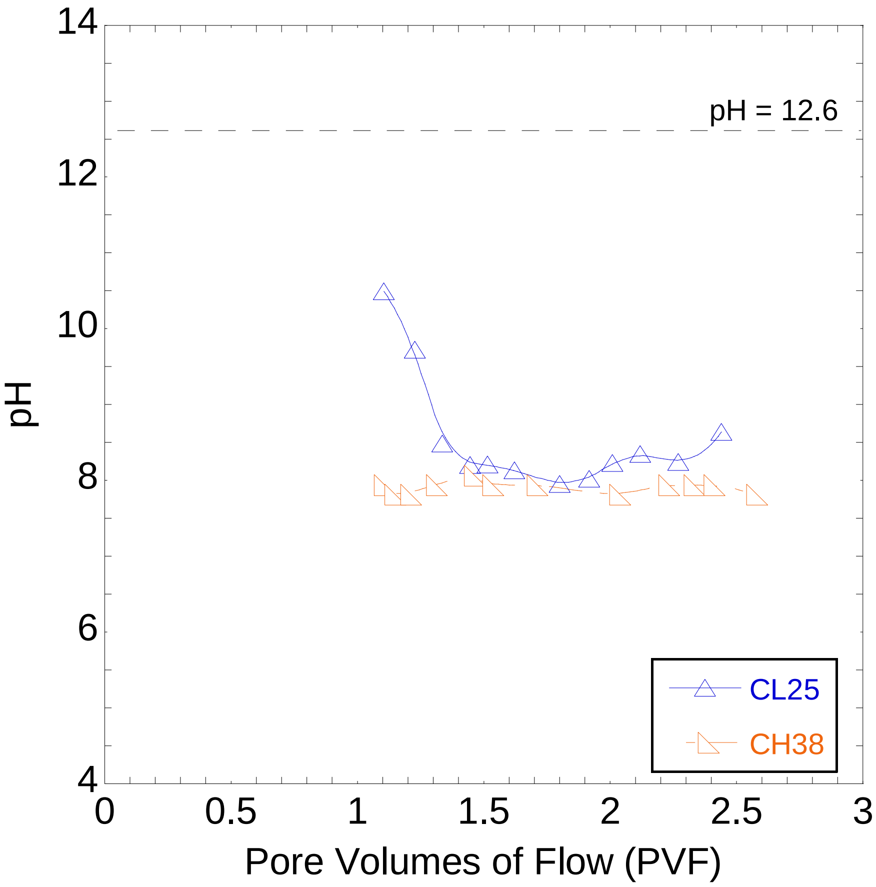
Soil ID	CEC (cmol$^+$/kg)	Atterberg Limits		Particle Size Fractions (%)			
		LL	PI	Gravel	Sand	Fines	2 µm Clay
SC-10	3.3	27	10	11.8	57.7	30.5	14.1
M-14	15.5	50	14	0.0	36.0	64.0	23.0
CL-25	28.1	42	25	0.0	1.1	98.9	31.4
CH-38	31.2	70	38	0.0	6.0	94.0	65.0

Mineralogy

Mineral Constituents	Chemical Formula	SC-10	M-14	CL-25	CH-38
Quartz	SiO_2	59	15	38	29
Albite Feldspar - $Ab_{82}An_{17}$	$(Na_{0.82}Ca_{0.17})AlSi_3O_8$	17	1	15	Trace
Orthoclase Feldspar	$KAlSi_3O_8$	14	-	8	Trace
Microcline Feldspar	$KAlSi_3O_8$	-	6	-	-
Calcite	$CaCO_3$	-	1	<0.5	-
Dolomite	$(Ca,Mg)(CO_3)_2$	4	<0.5	1	-
Siderite	$FeCO_3$	-	-	-	-
Hematite	alpha-Fe_2O_3	-	3	1	-
Akaganeite	beta-FeOOH	1	-	-	-
Pargasite	$NaCa_2Mg_4Al_3Si_6O_{22}(OH)_2$	-	3	-	-
Hornblende	$Ca_2(Mg,Fe)_5(Si,Al)_8O_{22}(OH)_6$	-	-	-	-
Kaolinite	$Al_2Si_2O_5(OH)_4$	2	69	4	37
Chlorite	$(Mg,Al)_6(Si,Al)_4O_{10}(OH)_8$	0	-	-	4
Illite/Mica	$KAl_2(Si_3AlO_{10})(OH)_2$	2	-	3	2
Montmorillonite	$Na_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2.XH_2O$	-	-	30	22
Mixed-Layered Illite/Smectite	$K_{0.5}Al_2(Si,Al)_4O_{10}(OH)_2 . 2H_2O$	1	2	-	6
Ratio of Illite/Smectite in Mixed-Layer		0.4	0.65	-	0.4

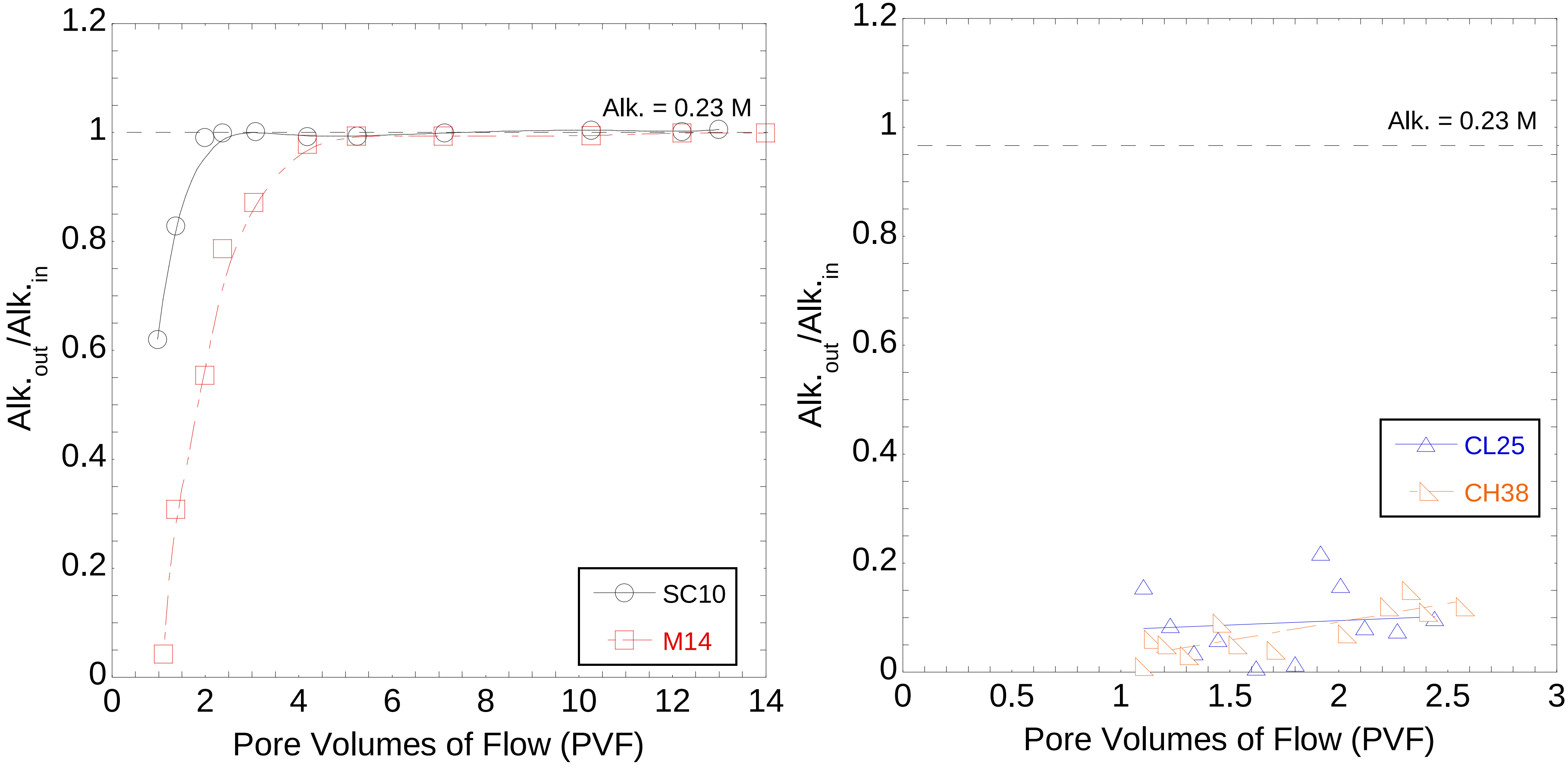
Breakthrough of pH in Subgrade Soil





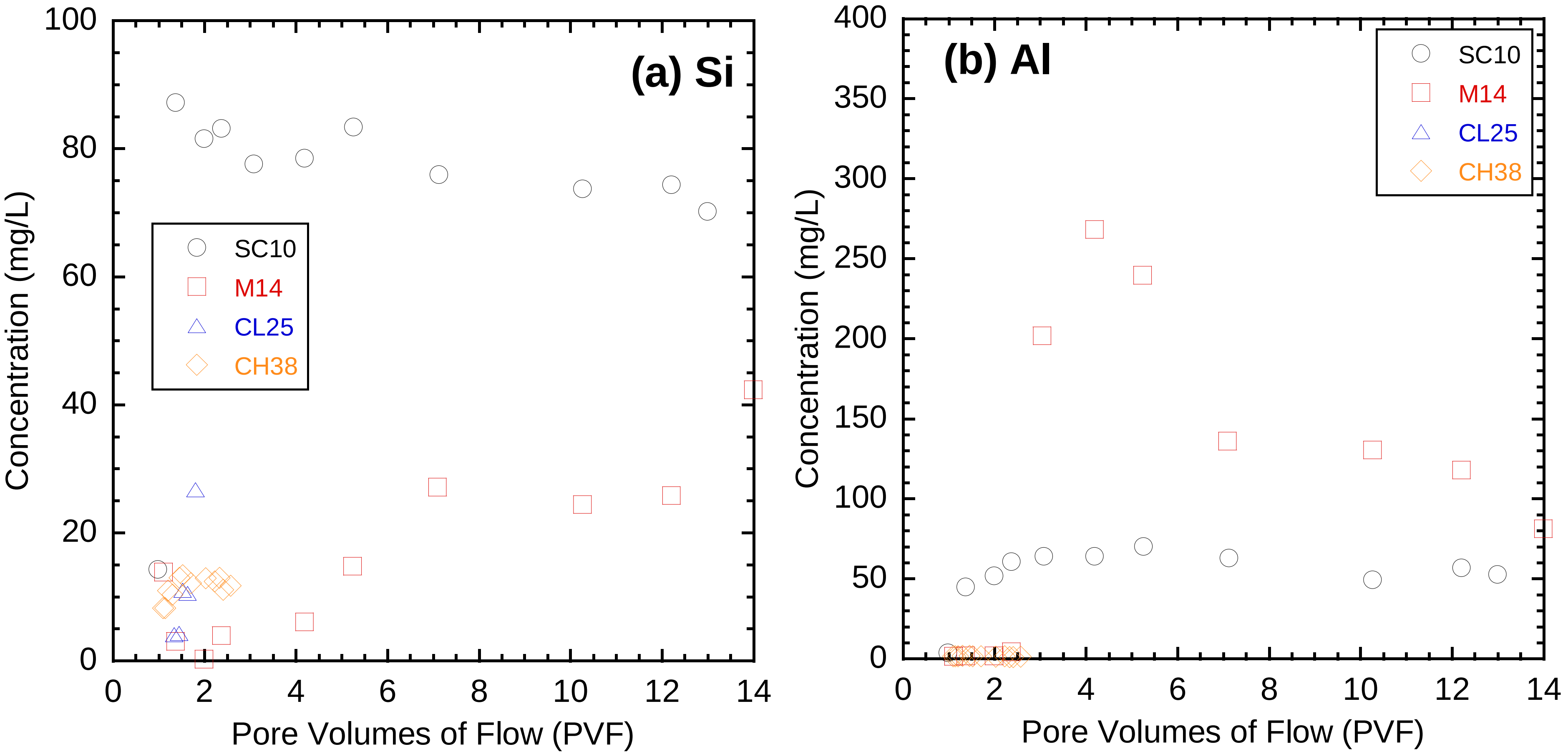
- SC-10: pH breakthrough on the 2nd day
- Clay minerals delay the breakthrough of pH, MMT has low permeability.

Breakthrough of Alkalinity in Soil



- SC-10: pH breakthrough on the 2nd day
- Clay minerals delay the breakthrough of alkalinity in the RCA leachate.

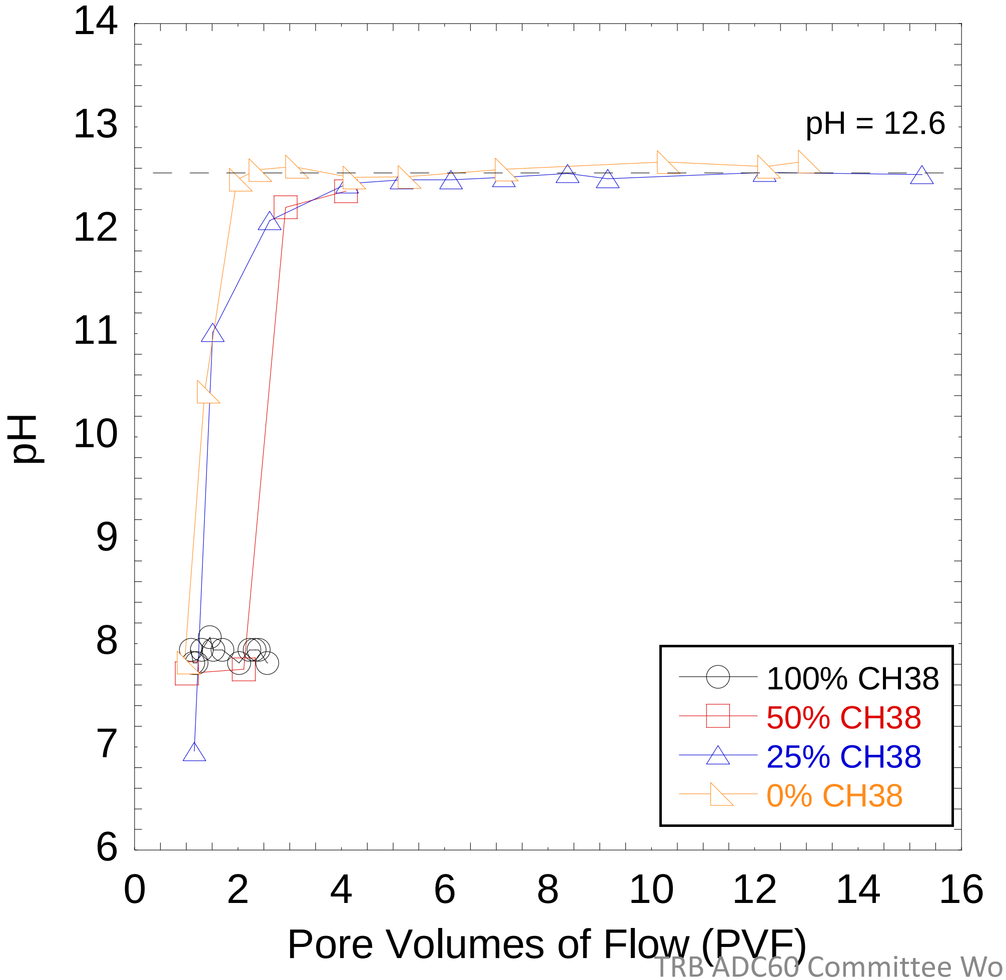
Mineral Dissolution



- Dissolution of Quartz and feldspar

Effect of CEC on the pH Buffering

- Create soil mixture with different CECs by mixing SC10 (CEC = 3 cmol+/kg) and CH38 (CEC = 31 cmol+/kg)



- Higher CEC results in delayed breakthrough
  - 0% - at 2 PVFs
  - 25% - 50% at 5 PVFs
  - 100% - hasn’t breakthrough (low permeability)

Conclusions

- ❑ Both high and low pH (range from 6.5 to 12.6) were observed during the field leaching tests on RCA.
- ❑ Sandy soil (containing major minerals of quartz and feldspar) has relatively low pH buffering, while soil with clay minerals (e.g., kaolinite, smectite) has higher pH buffering.
- ❑ Increase in CEC helps delay the breakthrough of pH.

Future Works

- ☐ Geochemical model:
  - 1D transportation of pH and Alkalinity through a soil column
- ☐ Carbonation effect on the pH and alkalinity of RCA
  - Previous results showed carbonation consumes the alkaline substance, and RCA presented lower pH in the field
- ☐ Forensic field Work at MnRoad:
  - Sampling the RCA in July and run laboratory leaching tests

Acknowledgement

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Thank you for your attention!

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