TDS RELATED LEACHING POTENTIALS OF COAL SPOIL AND REFUSE FROM TN AND VA

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Surface coal mining in the central Appalachian coalfields generates large quantities of overburden waste rock (spoil) which is removed to access coal seams.

Diverse coal spoil and refuse materials are commonly disposed of into highwall backfills and river valleys (valley fills).

Over the past decade, concerns have emerged over the biological effects of elevated TDS emissions from backfills and valley fills to surface water.

By understanding the leaching potential of diverse spoil and refuse materials, VFs may be designed to minimize environmental impacts.

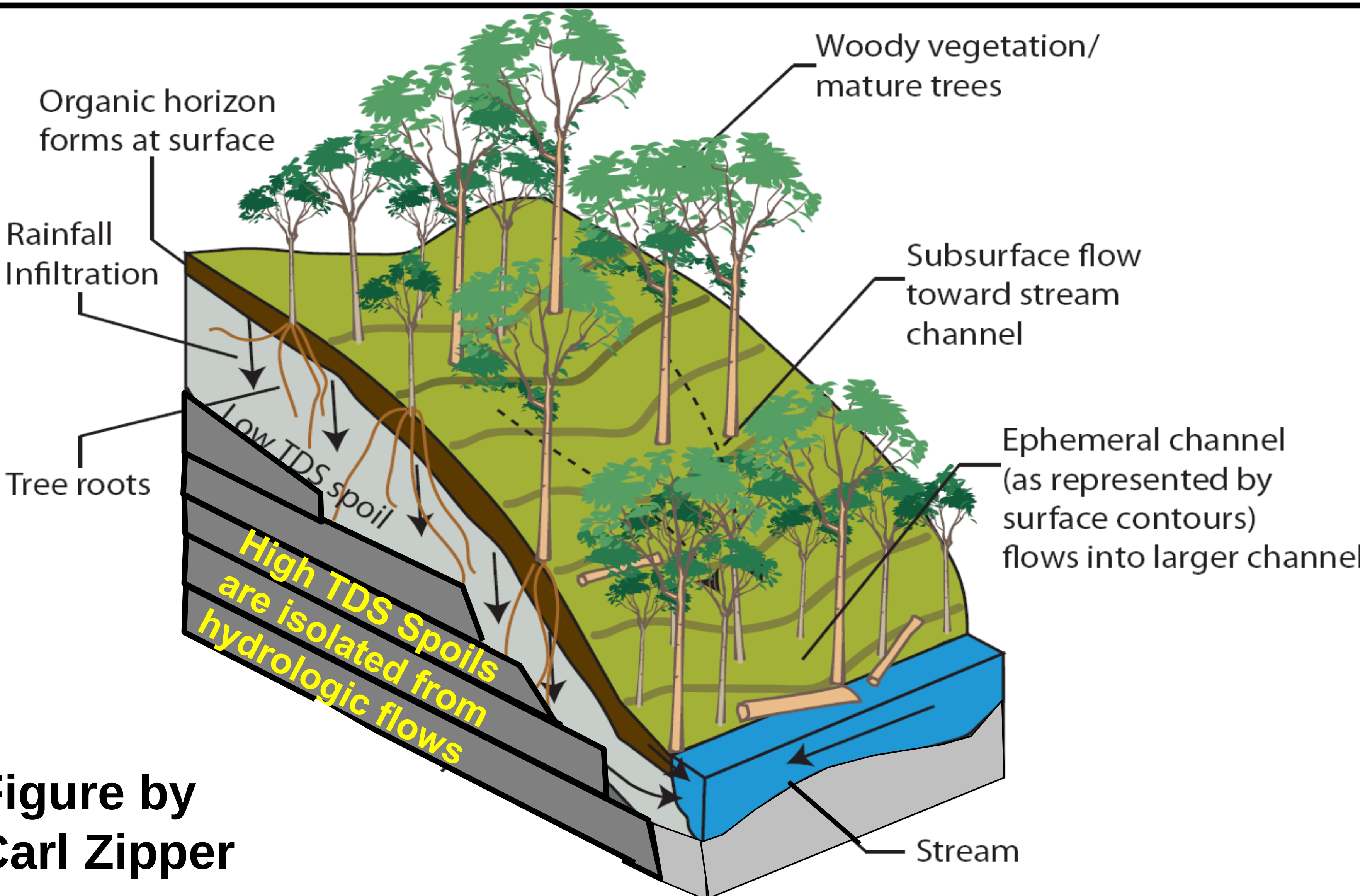
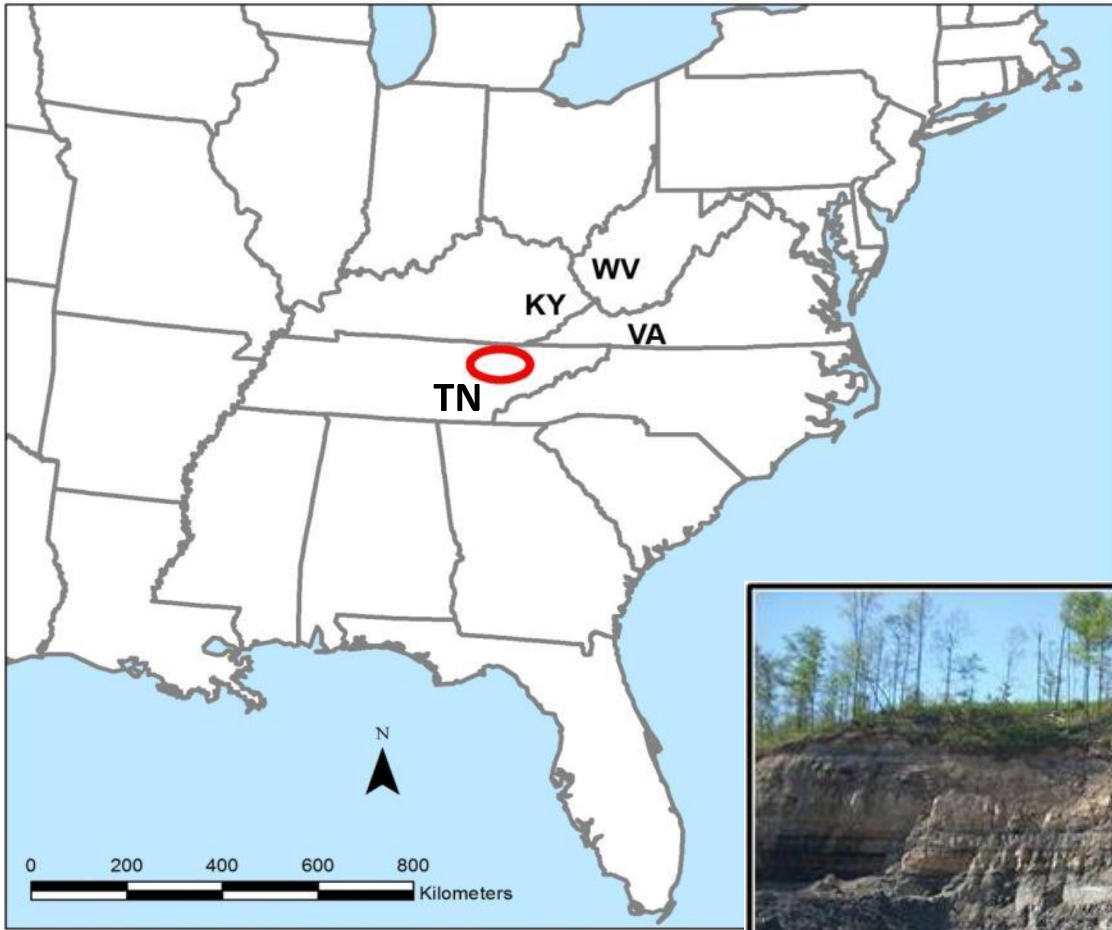
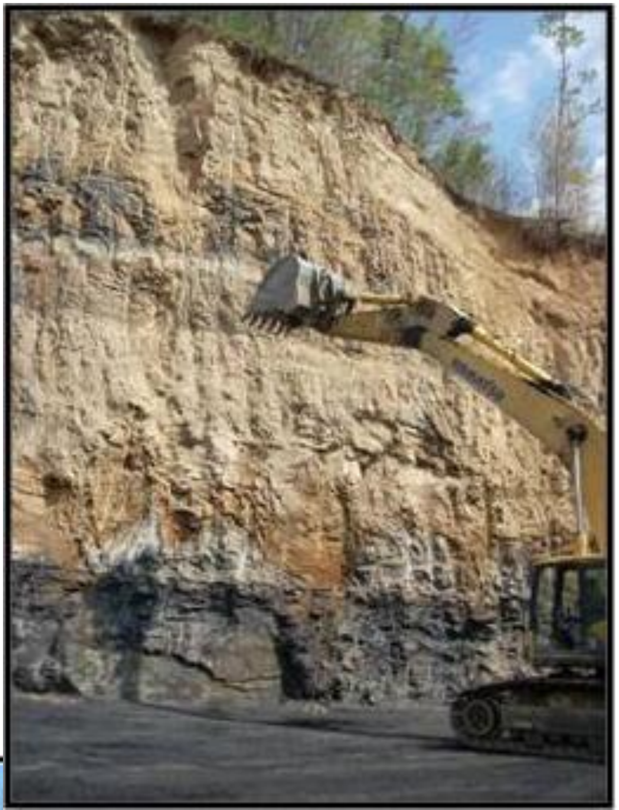


Figure by Carl Zipper

SPOIL AND REFUSE SAMPLES FROM TENNESSEE





OBJECTIVE

To characterize the potential leaching behavior of 5 mine spoil and 4 refuse materials, in terms of:

- pH
- EC
- Major cation and anion composition

METHODS

BULK SAMPLES (2 5-gal buckets) were each:

- Spread out to air-dry.
- Passed through a 1.25 cm (0.5”) sieve.
- Coarse fraction was crushed to <1.25 cm.
- All material was thoroughly re-blended.
- Subsamples (1200 cm^3, with mass recorded) were collected (cone and quarter) for column leaching and to determine pore volume (within columns).
- Subsamples were collected and crushed as appropriate for basic characterization including saturated paste pH/EC, Peroxide Potential Acidity (PPA), and Acid-Base Accounting.

COLUMN SETUP

Capped with 5 cm sand

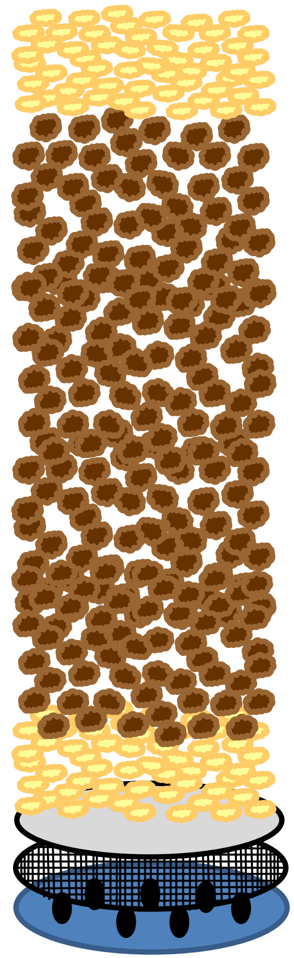
- Sample volume: 1200 cm^3
- Inside diameter = 7.5 cm
- Height of spoil = ~ 27 cm
- Inside bottom of column:

  -- 5 cm (2”) sand

  -- Whatman #1 filter

  -- 0.1 mm nylon mesh

  -- perforated plastic disc



- PVC pipe nipple and Tygon tubing for drainage

30
29
28
45
44
43
EMERGENCY
FIRST AID KIT

METHODS

- Each spoil material was run in triplicate (3 columns/material)
- Unsaturated: samples initially moistened to maximum water holding, then any amount added = amount drained.
- Saturated: samples initially slowly saturated, maintained with ~1cm of leaching solution above the sand layer.
- Leaching solution: synthetic acid rain with pH=4.6
  Contains very low amounts of $CaSO_4$, K_2SO_4, Mg_2SO_4, NaCl, $NaNO_3$, NH_4NO3, $(NH_4)_2SO_4$, H_2SO_4, HNO_3, H_3PO_4)
  (Recipe from Halvorson and Gentry, 1990)
- Simulated rainfall was applied 2x/week (Mon/Thurs)
- Each rainfall event = 125 ml (~2.5 cm; 1”)
- Leachate (~125 ml) collected after ~24 hrs (Tues/Fri).
- Samples analyzed for: pH, EC, several cations, bicarbonate, sulfate, and chloride

BULK SAMPLE CHARACTERIZATION - SPOIL

		Saturated paste						
		pH	EC (uS/cm)	PPA	Total-S %	MPA	CCE	NNP
SPOIL	**TN-1**	7.26	2250	0.0	0.06	1.82	31.4	29.6
	TN-2	7.80	2610	0.0	0.12	3.68	52.3	48.6
	TN-3	7.52	2680	0.0	0.09	2.88	24.4	21.5
	TN-4	4.68	1930	-0.3	0.08	2.62	29.0	26.4
	TN-5	5.84	2570	-0.6	0.15	4.61	36.4	31.8

- Range from acidic (4.68) to alkaline (7.80)
- Moderate soluble salt content
- Not predicted to be acid forming by PPA or NNP

BULK SAMPLE CHARACTERIZATION - REFUSE

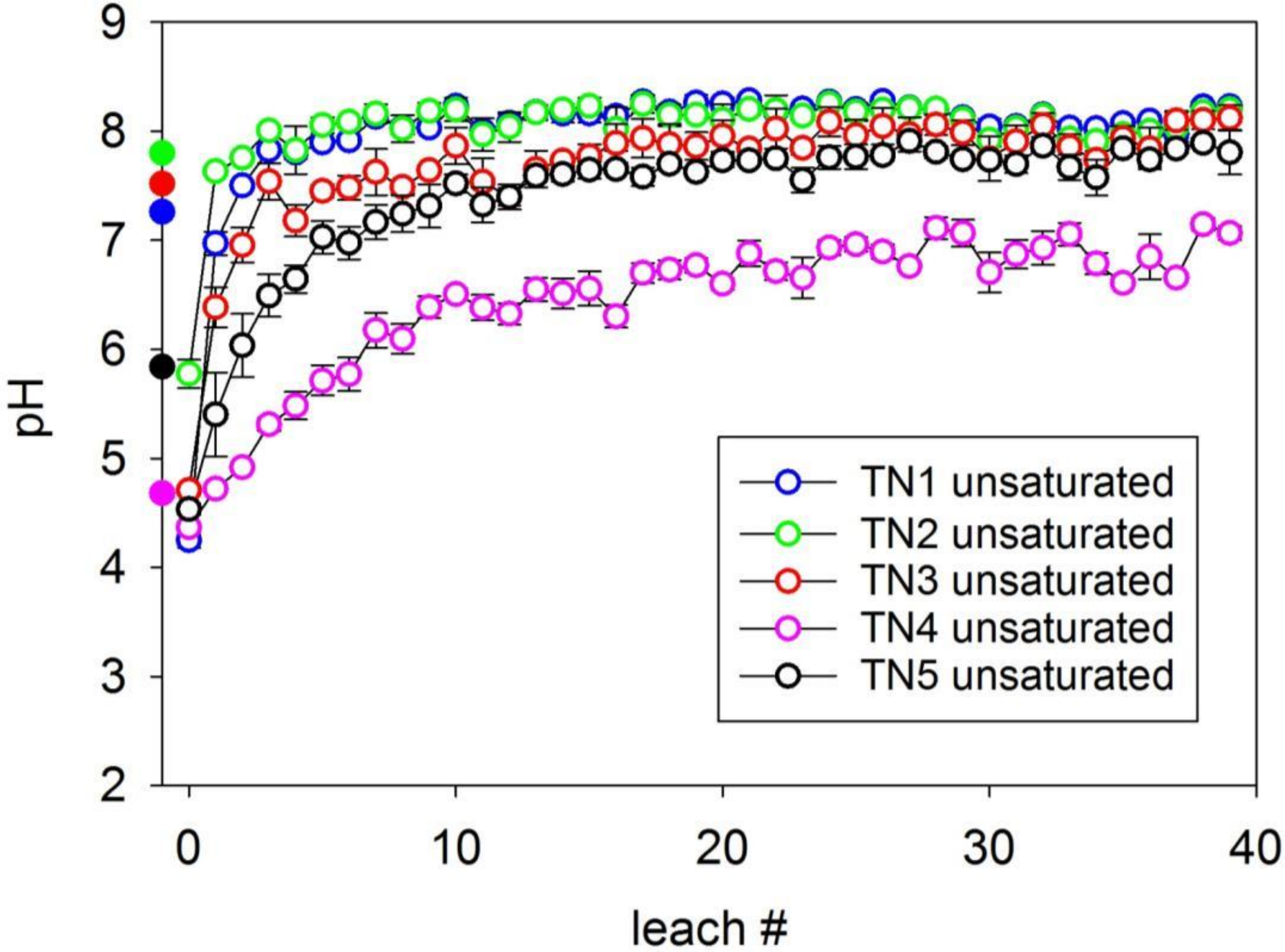
		Saturated paste						
		pH	EC (uS/cm)	PPA	Total-S %	MPA	CCE	NNP
REFUSE	VA-21	8.75	900	-31.2	1.25	39.21	60.0	20.8
	TNR-1	7.95	1261	-8.3	0.52	16.25	69.7	53.5
	TNR-2	8.03	2820	0.0	1.09	34.1	75.8	41.7
	TNR-3	8.08	1945	-20.5	1.22	38.02	61.3	23.3

- Alkaline
- Moderate soluble salt content
- 3 samples predicted to be acid forming by PPA
- None predicted to be acid forming by NNP

pH: UNSATURATED SPOIL

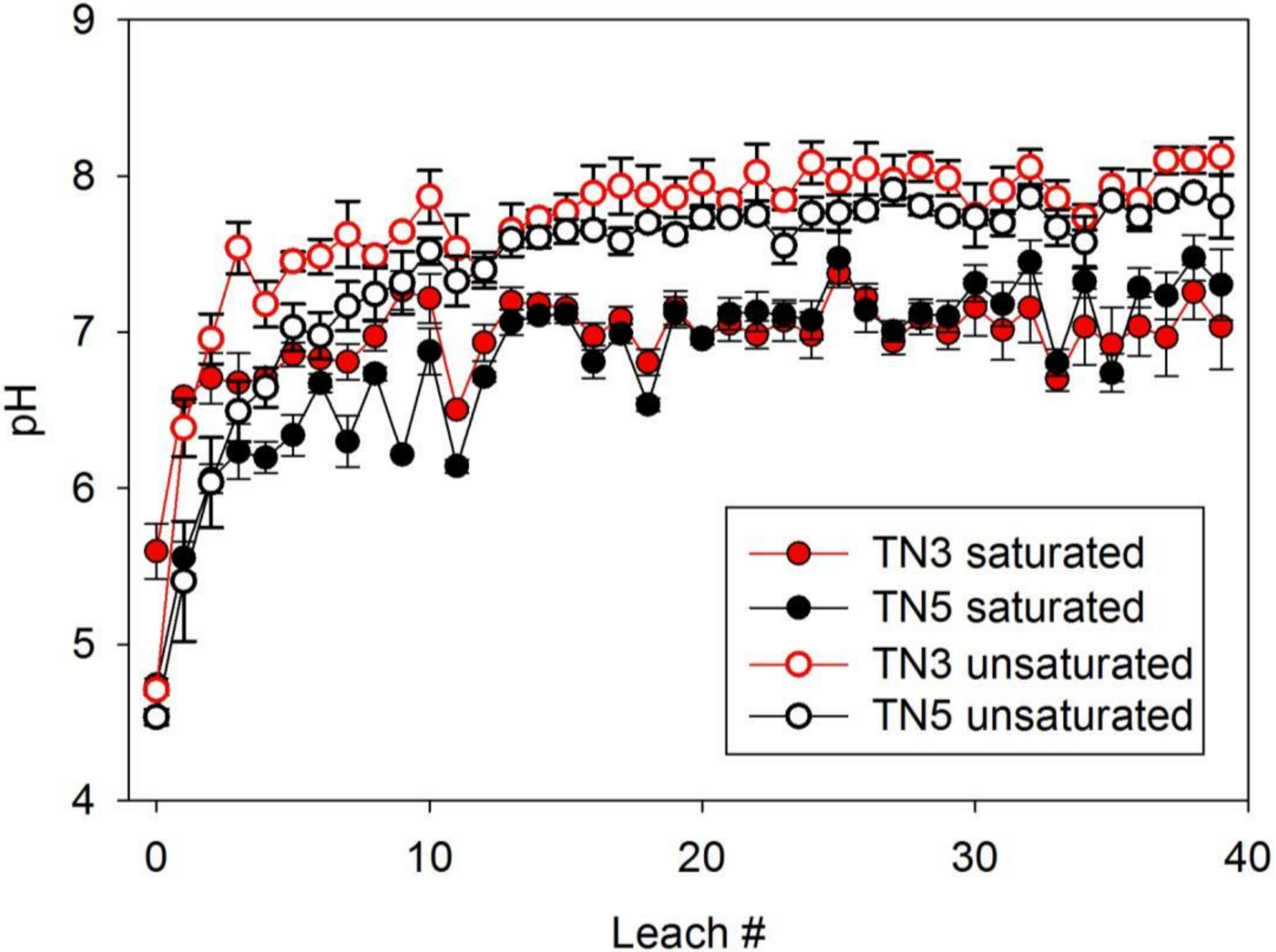
pH equilibrated within 10 – 20 leach events (3+ pore volumes)

pH equilibrated ~ 6.9 – 8.2



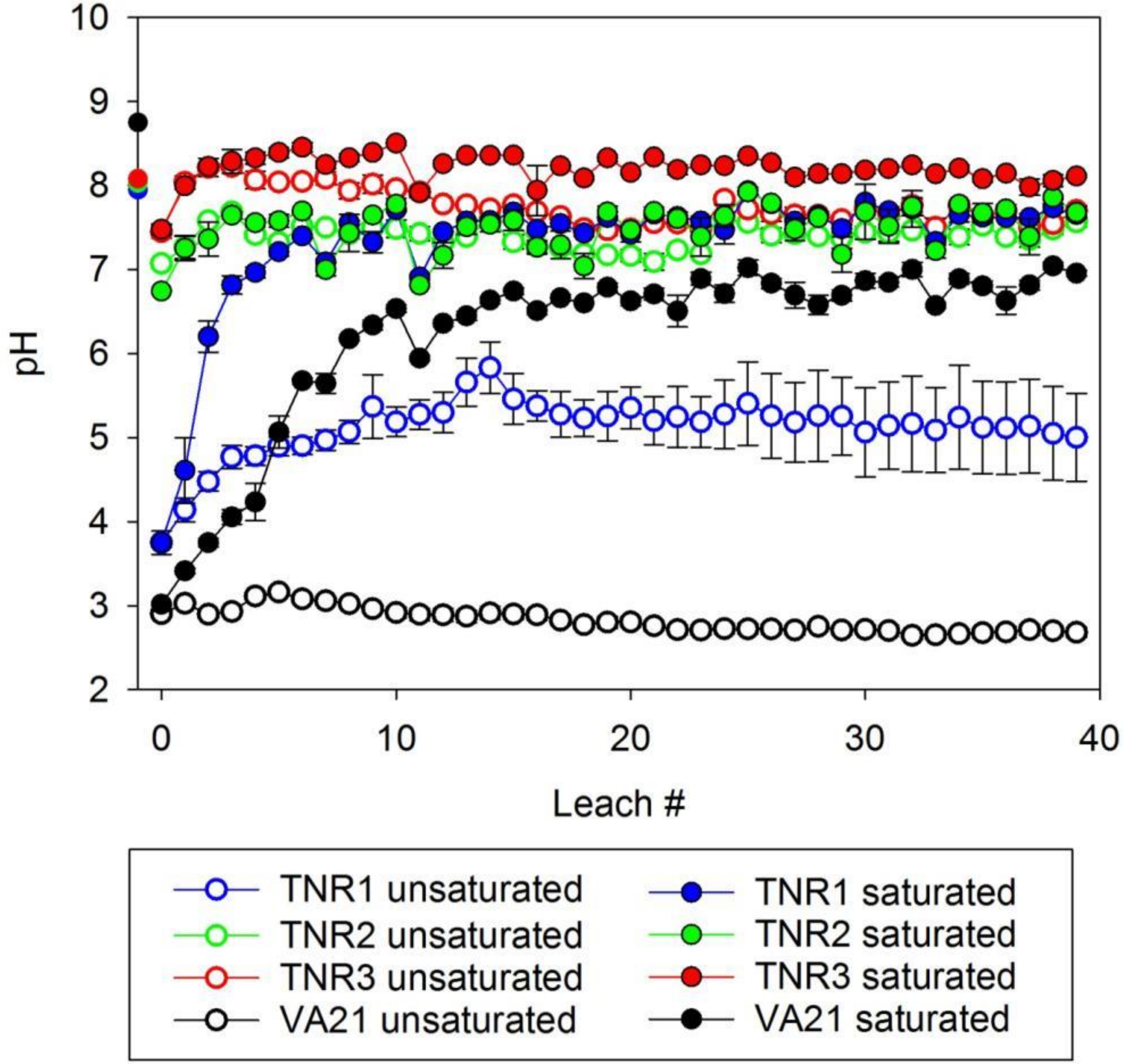
pH: SATURATED VS UNSATURATED SPOIL

Unsaturated pH > Saturated pH



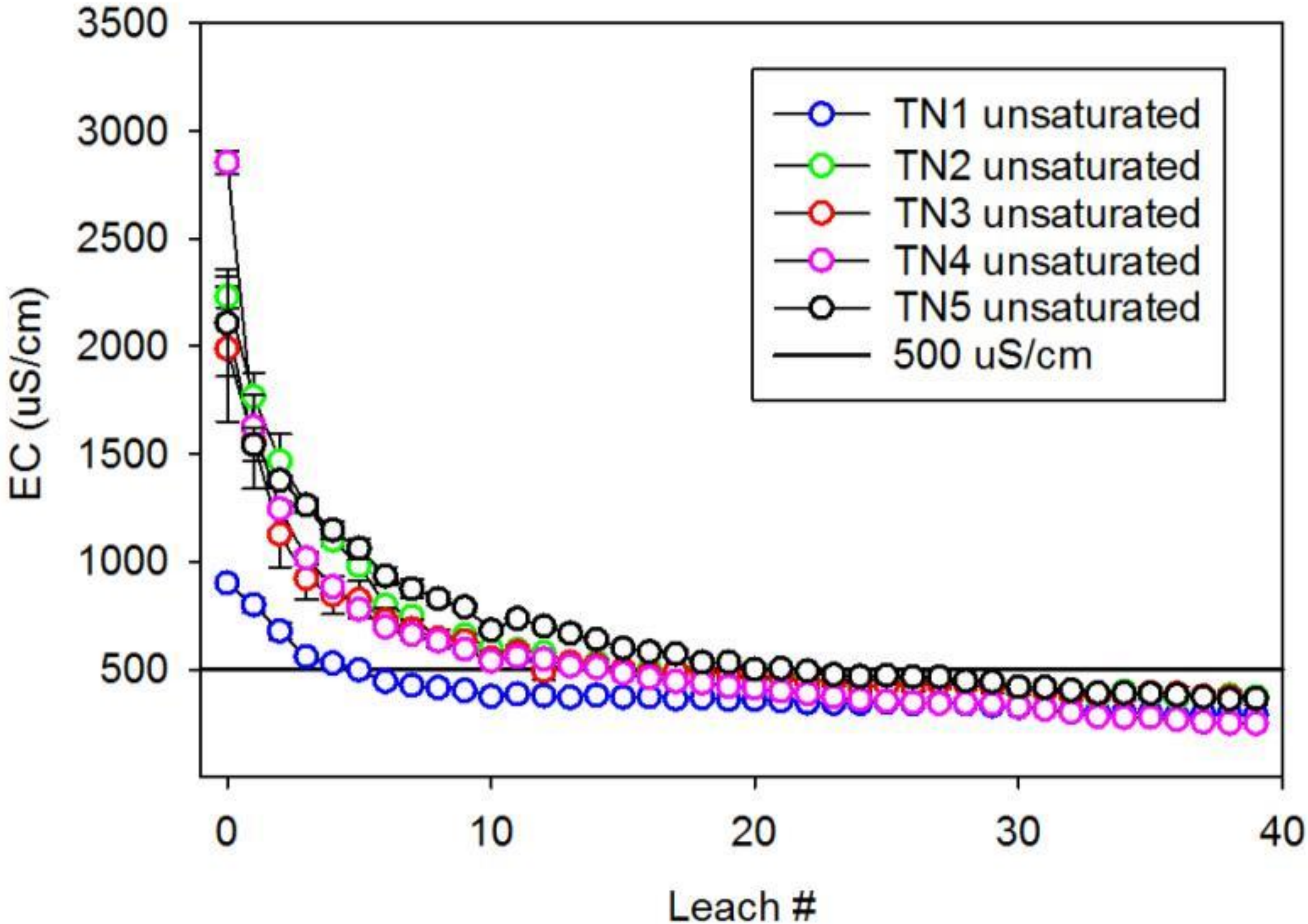
pH: REFUSE

Unsaturated pH (2.6 – 7.6) < Saturated pH (6.9 – 8.2)

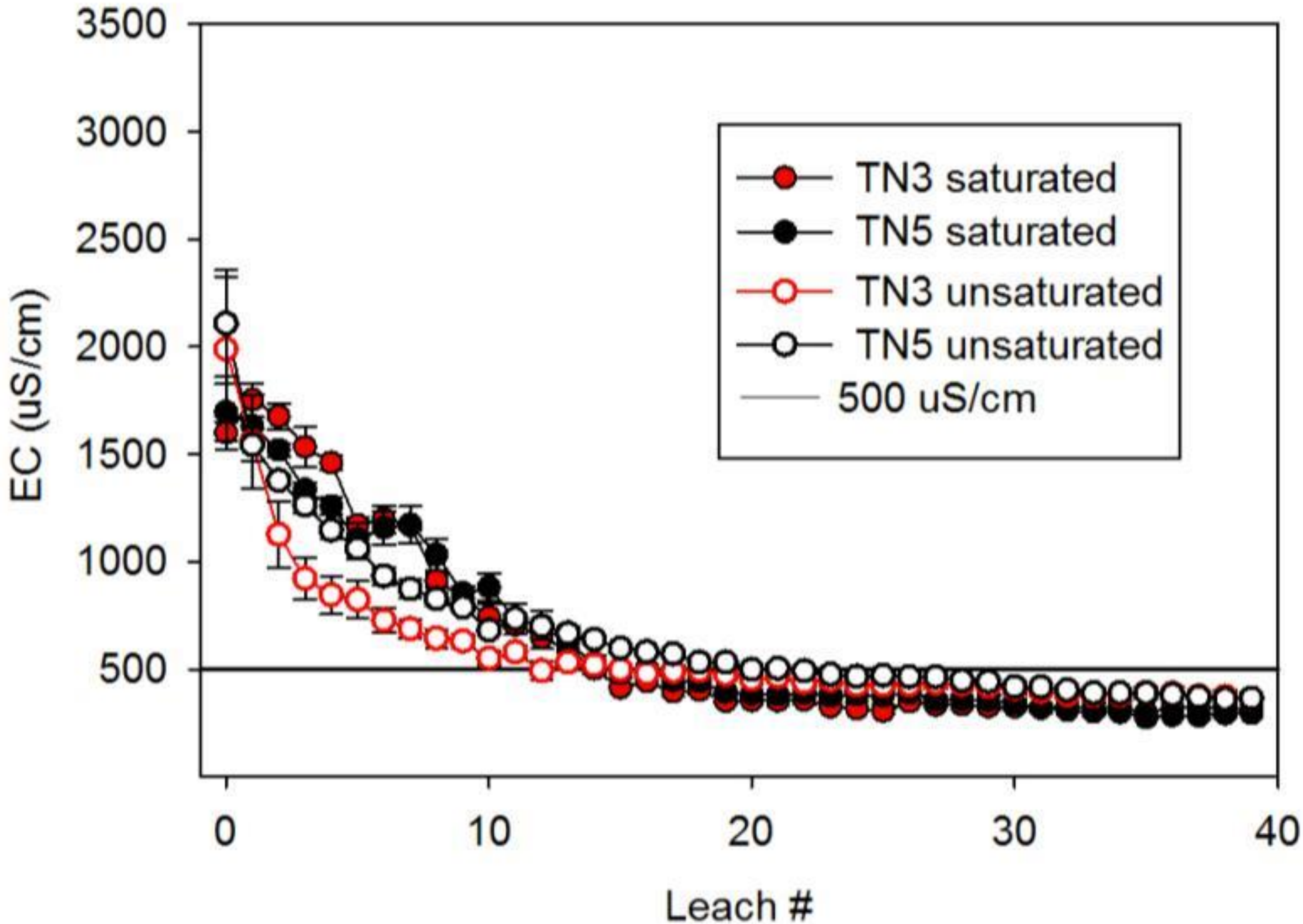


	%S	CCE
VA21	1.25	60.0
TNR1	0.52	69.7
TNR2	1.09	75.8
TNR3	1.22	61.3

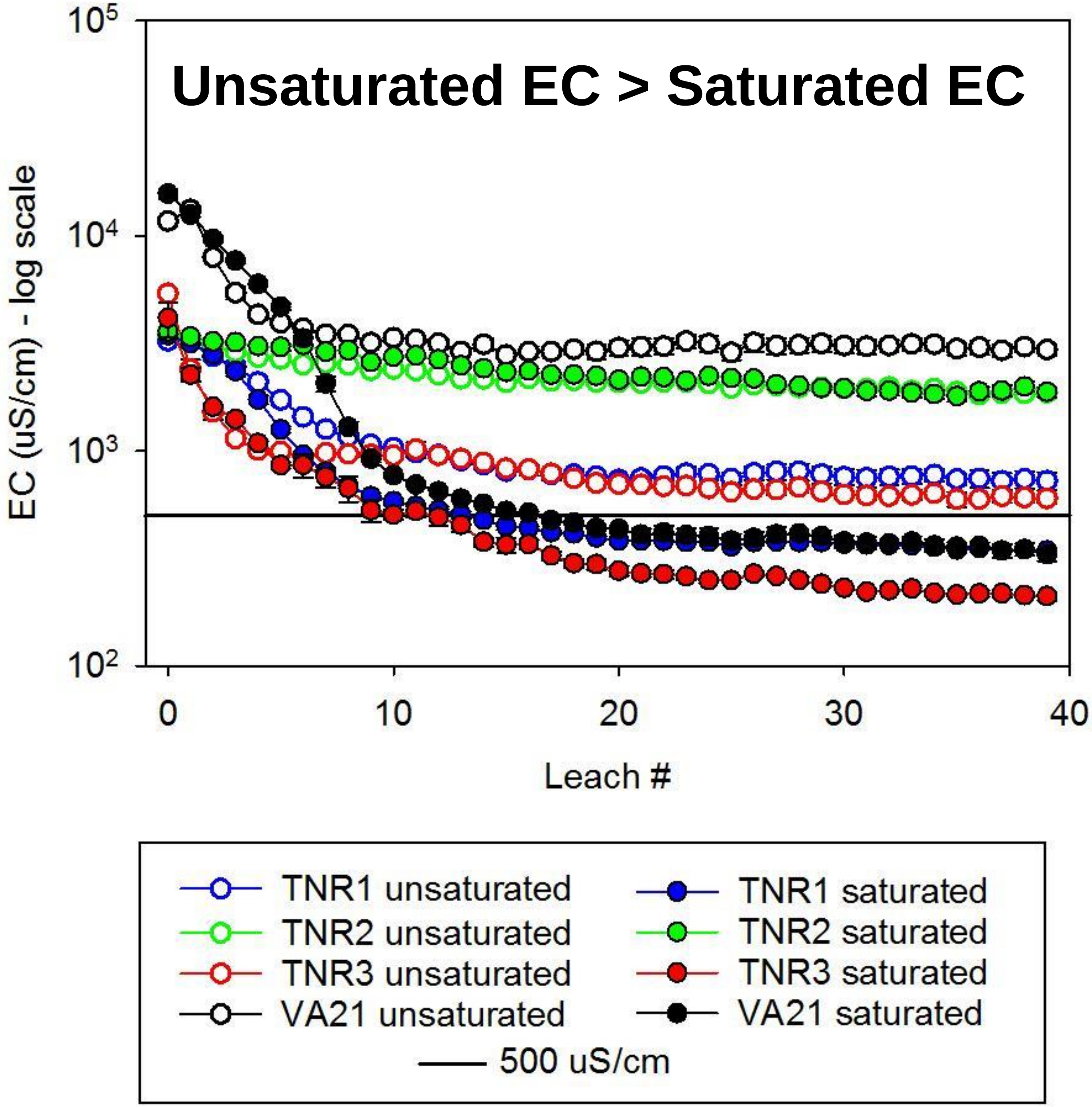
EC: UNSATURATED SPOIL



EC: SATURATED VS UNSATURATED SPOIL



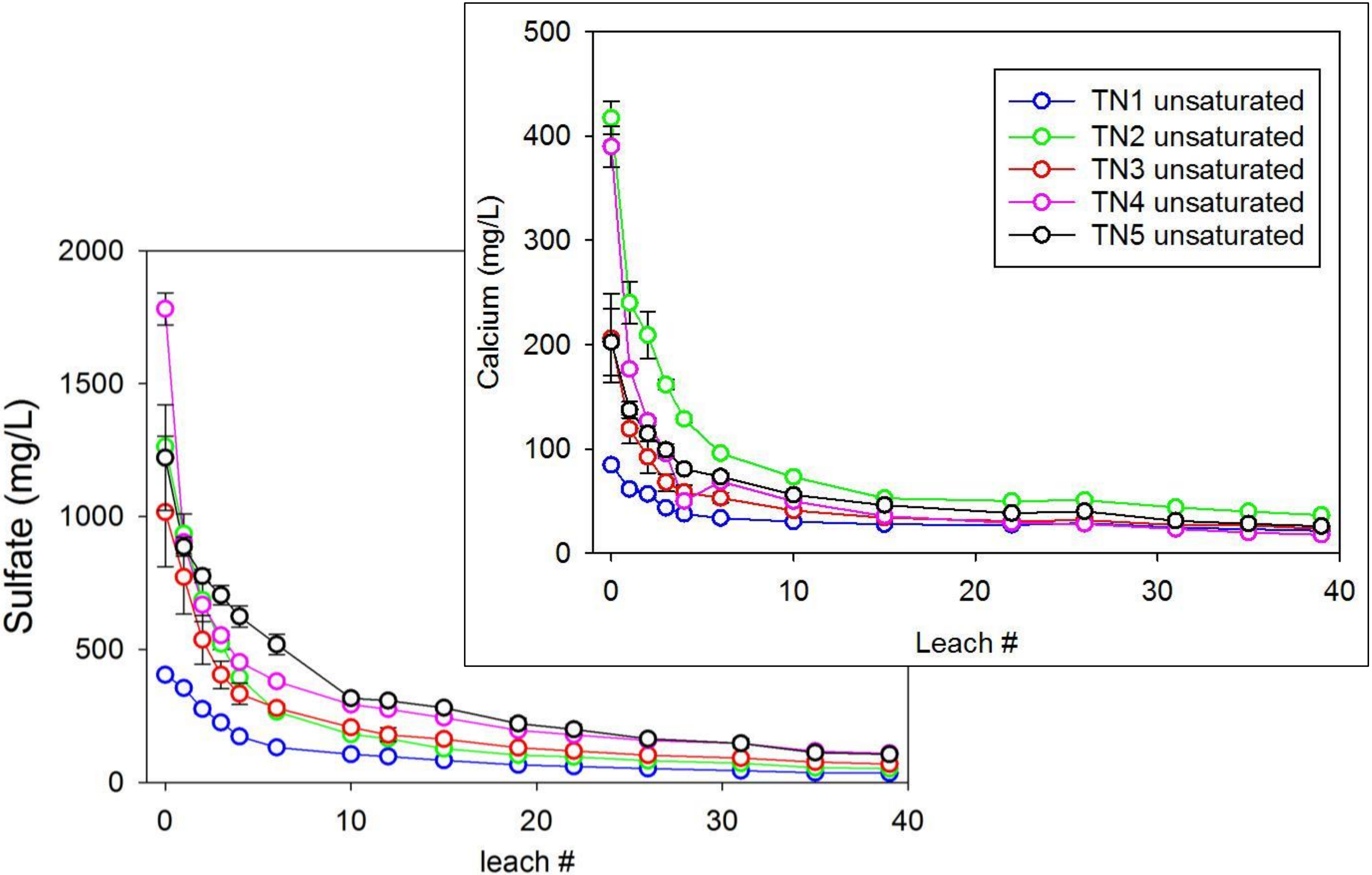
EC: REFUSE



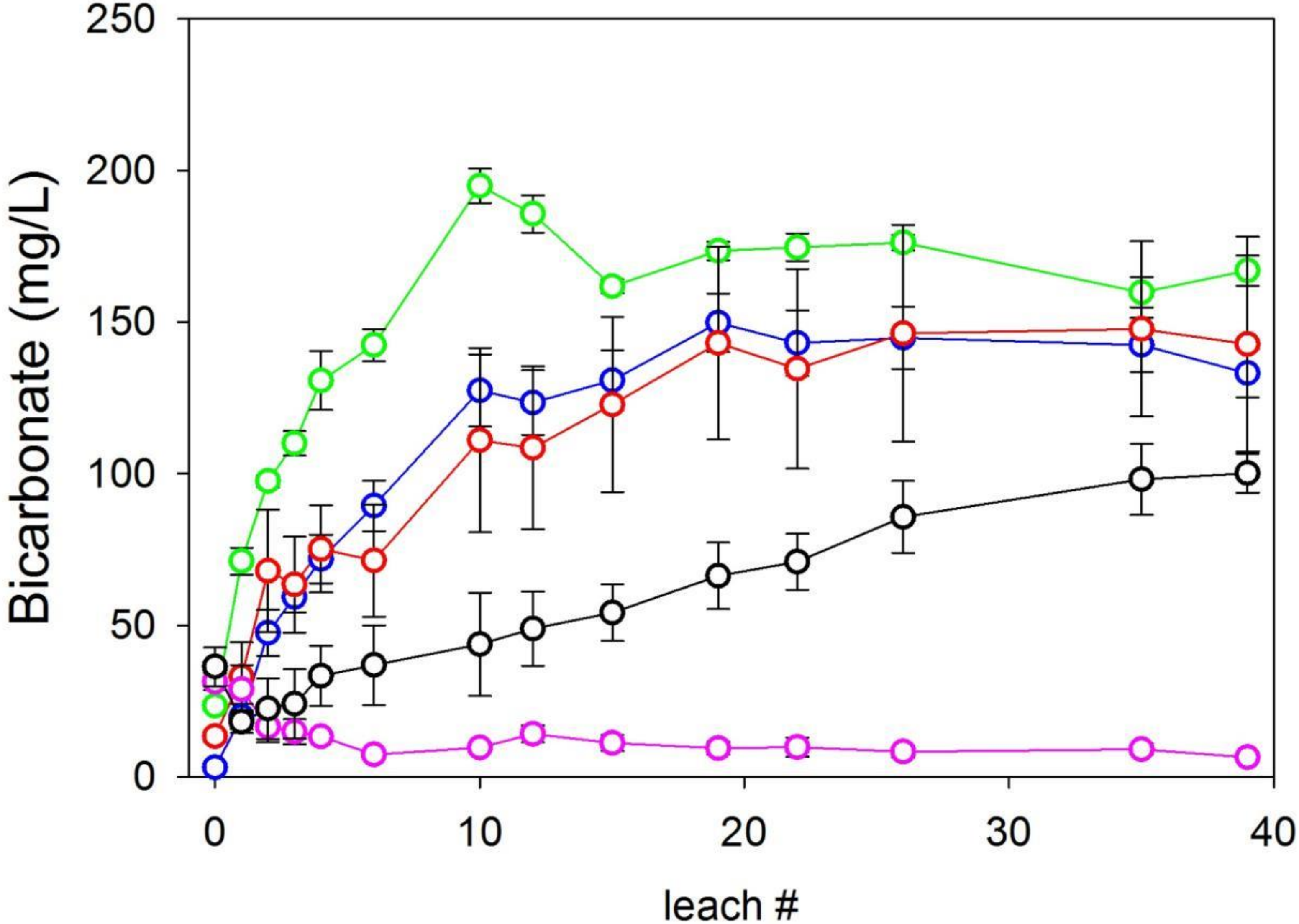
	%S	CCE
VA21	1.25	60.0
TNR1	0.52	69.7
TNR2	1.09	75.8
TNR3	1.22	61.3

SPOIL:

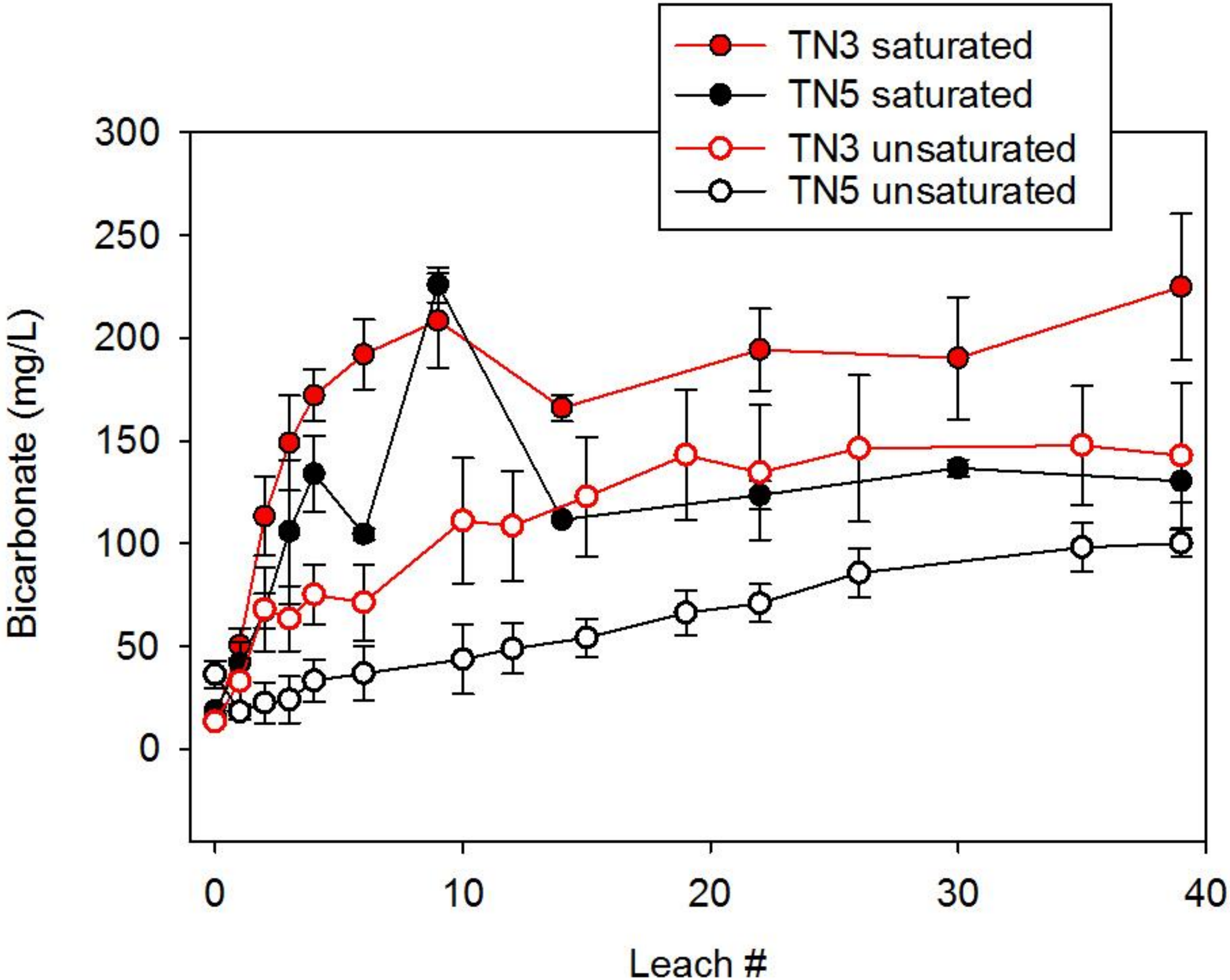
Most ions exhibited release curves similar to EC.



SPOIL: Bicarbonate was the only major ion that increased over time (for most samples).



SPOIL: Bicarbonate release was higher under saturation.



REFUSE

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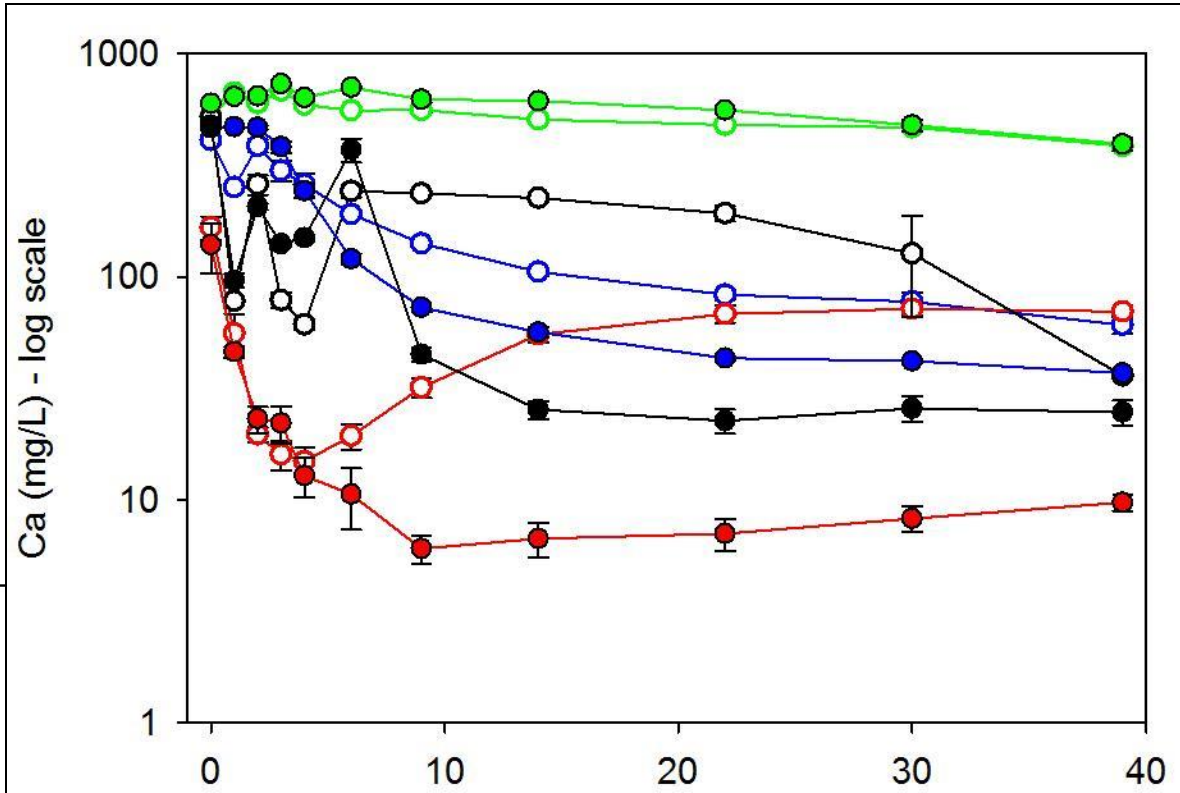
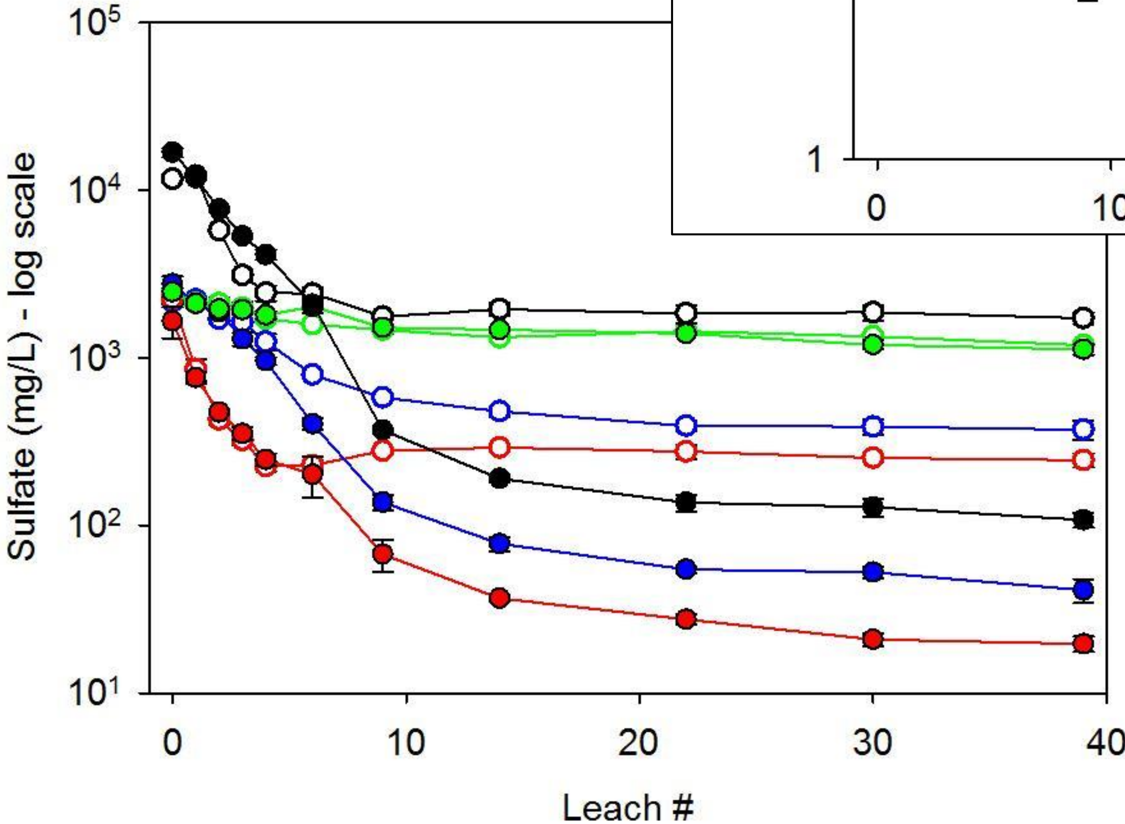
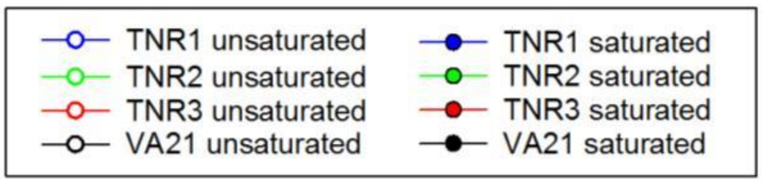
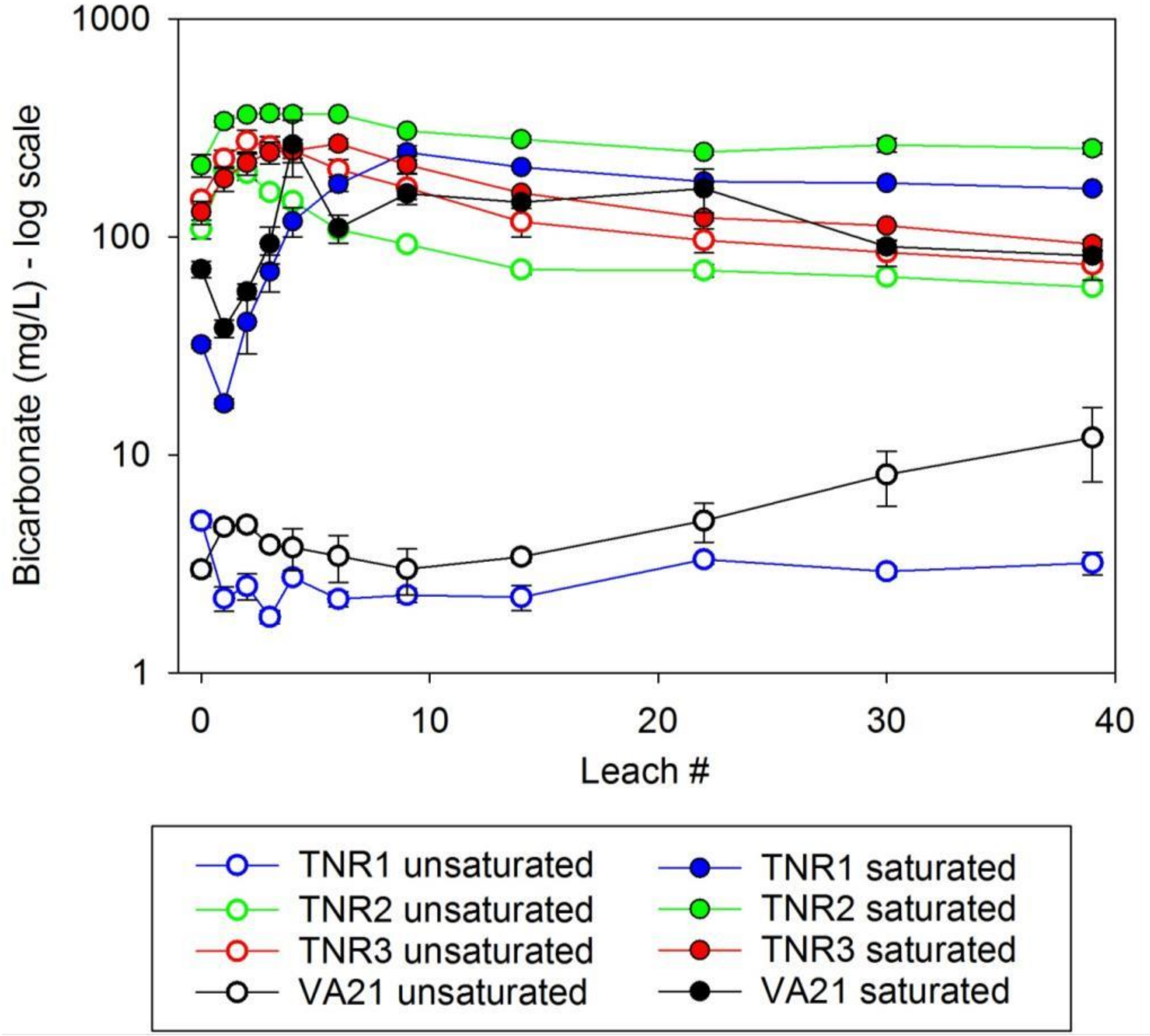






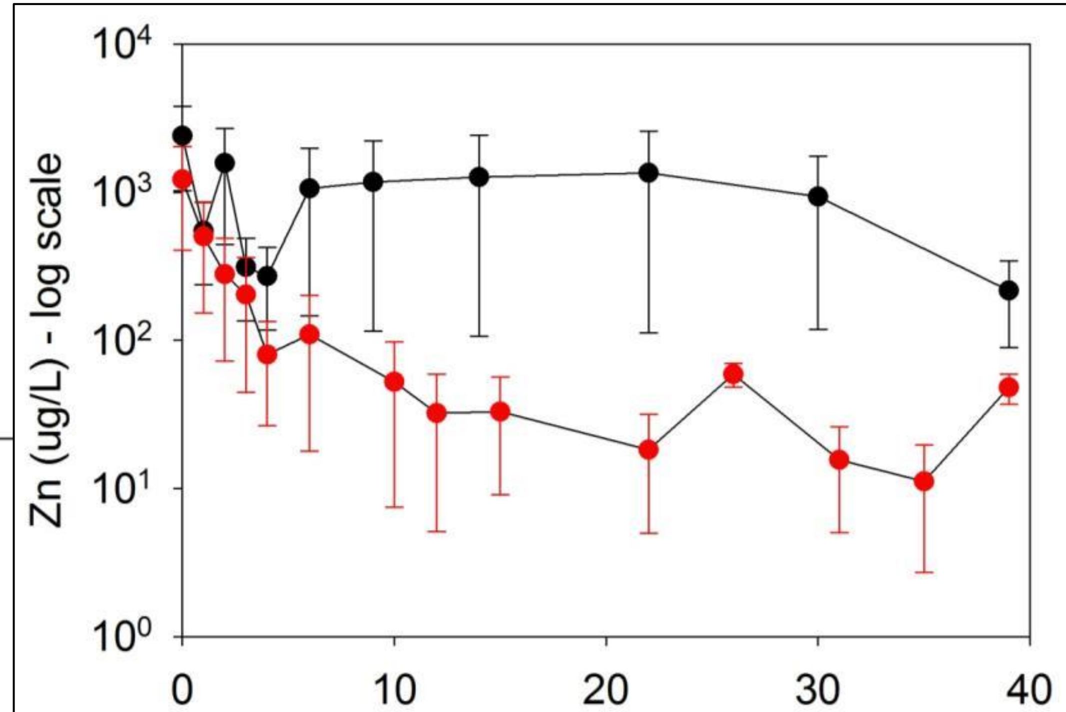
REFUSE

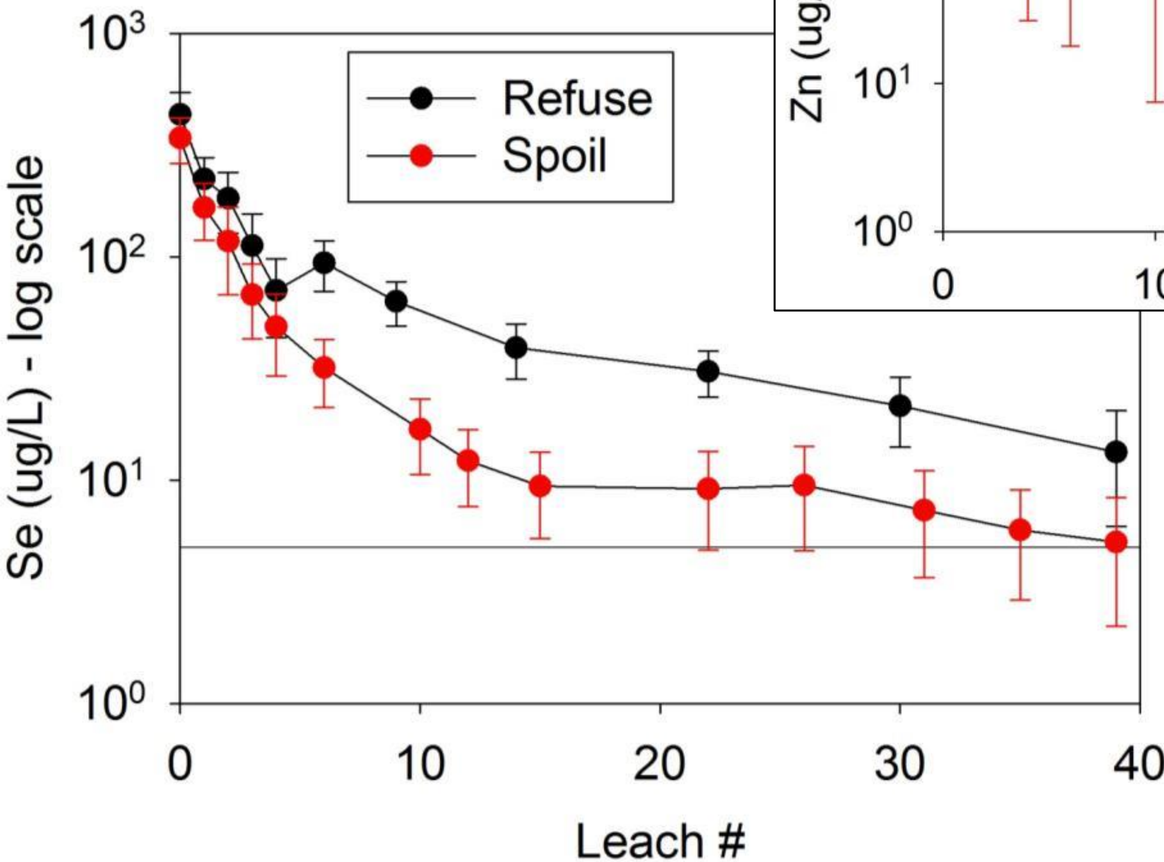


1000
100
10
1
Bicarbonate (mg/L) - log scale
0
10
20
30
40
Leach #
TNR1 unsaturated
TNR2 unsaturated
TNR3 unsaturated
VA21 unsaturated
TNR1 saturated
TNR2 saturated
TNR3 saturated
VA21 saturated

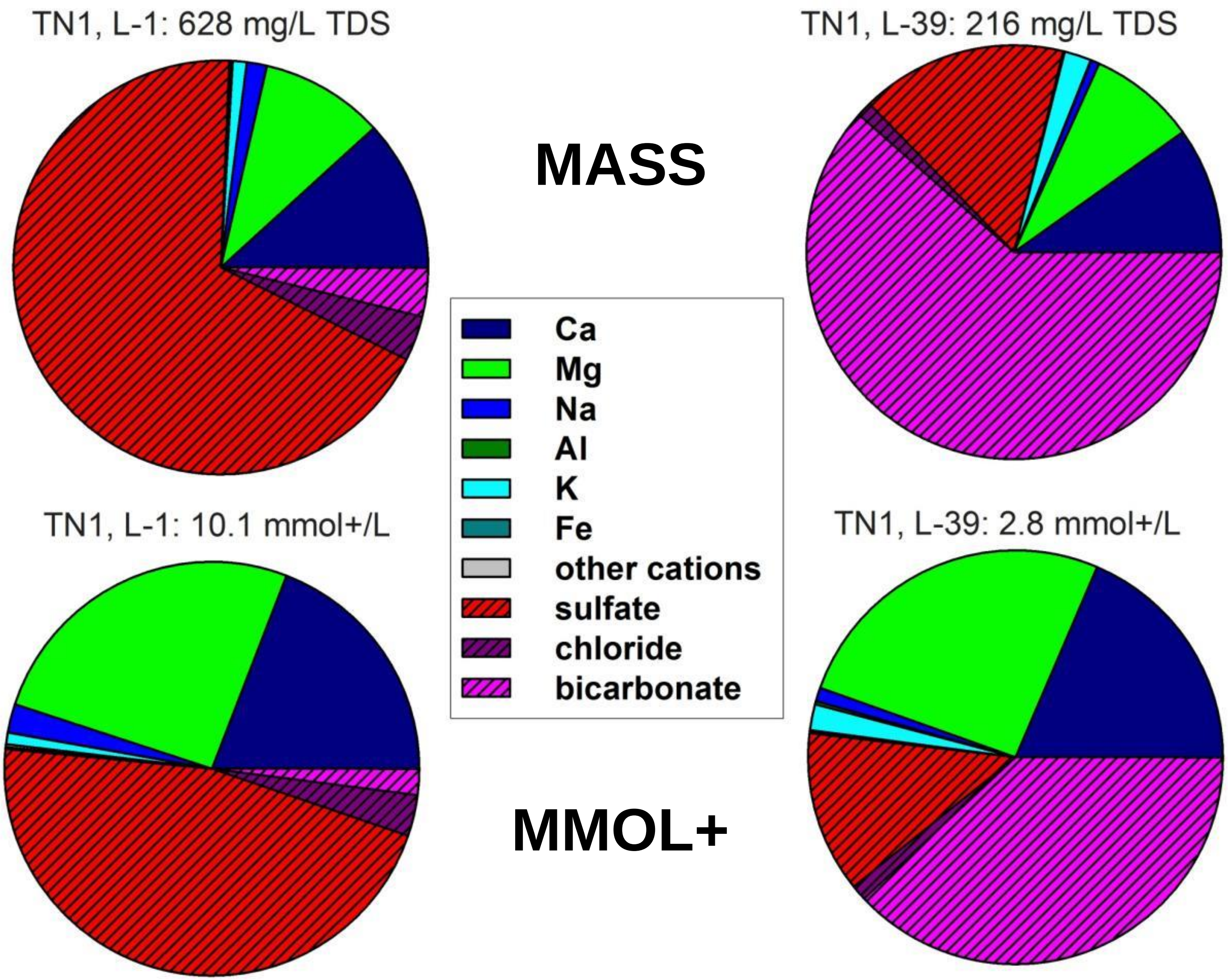
TRACE/MINOR ELEMENTS: REFUSE vs SPOIL

Overall release is greater from refuse than from spoils.



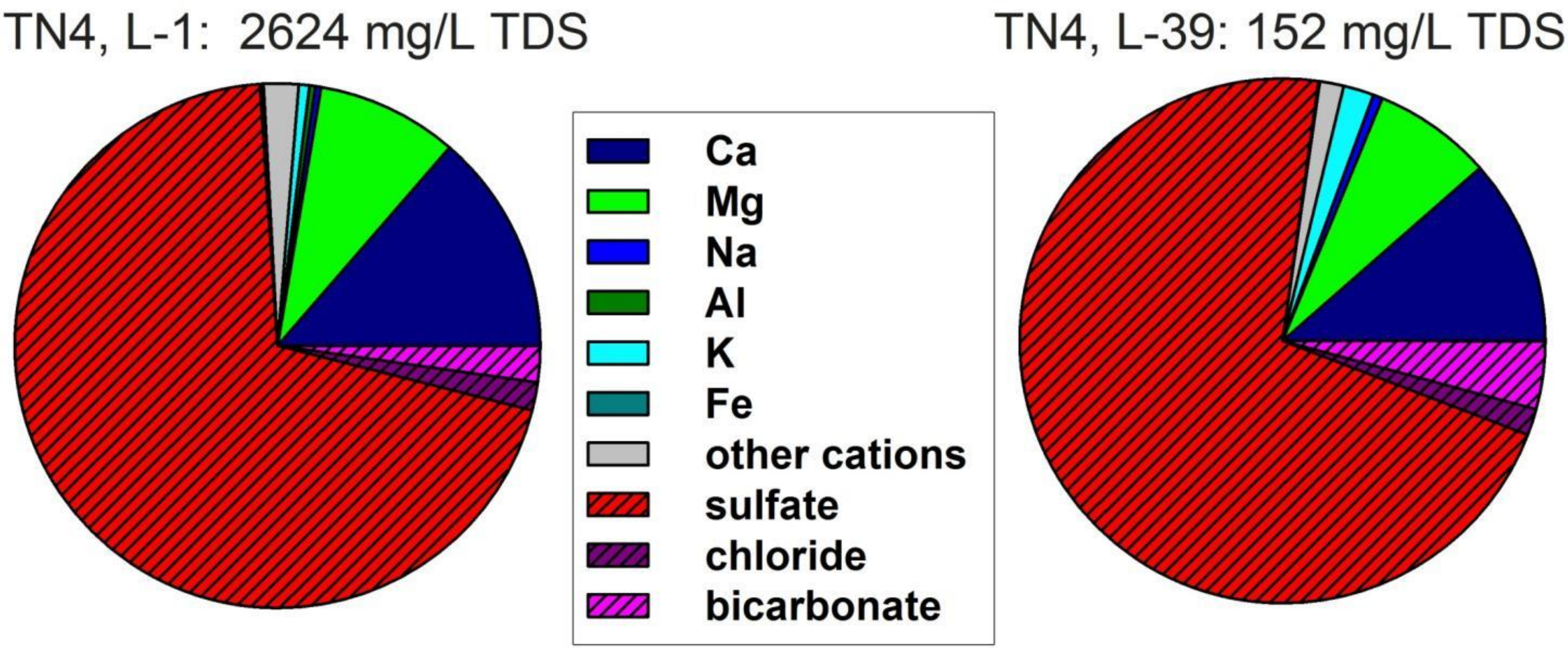


UNSATURATED SPOIL – TN1



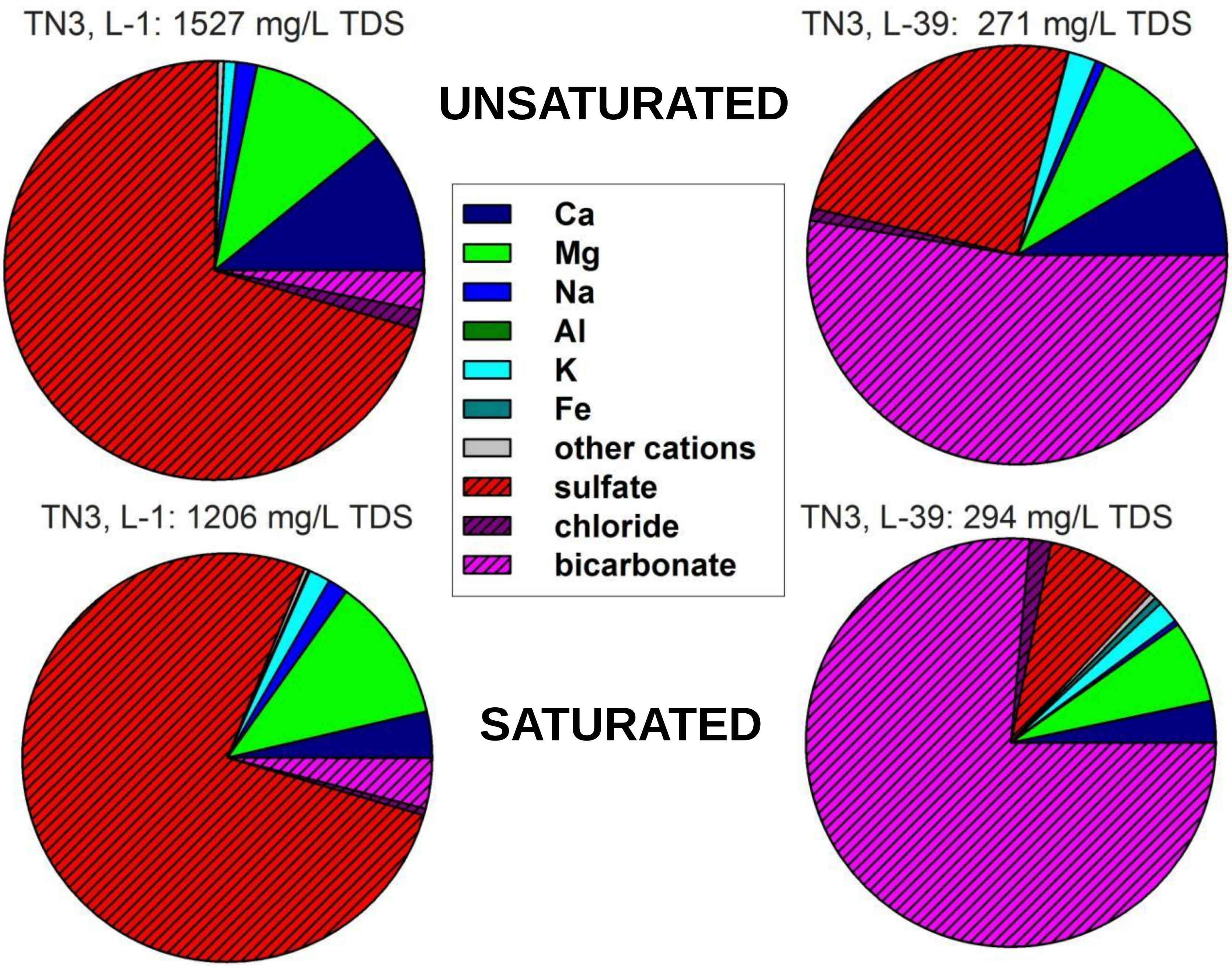
Note shift to bicarbonate over time; similar for TN2, TN3, and TN5.

UNSATURATED SPOIL – TN4

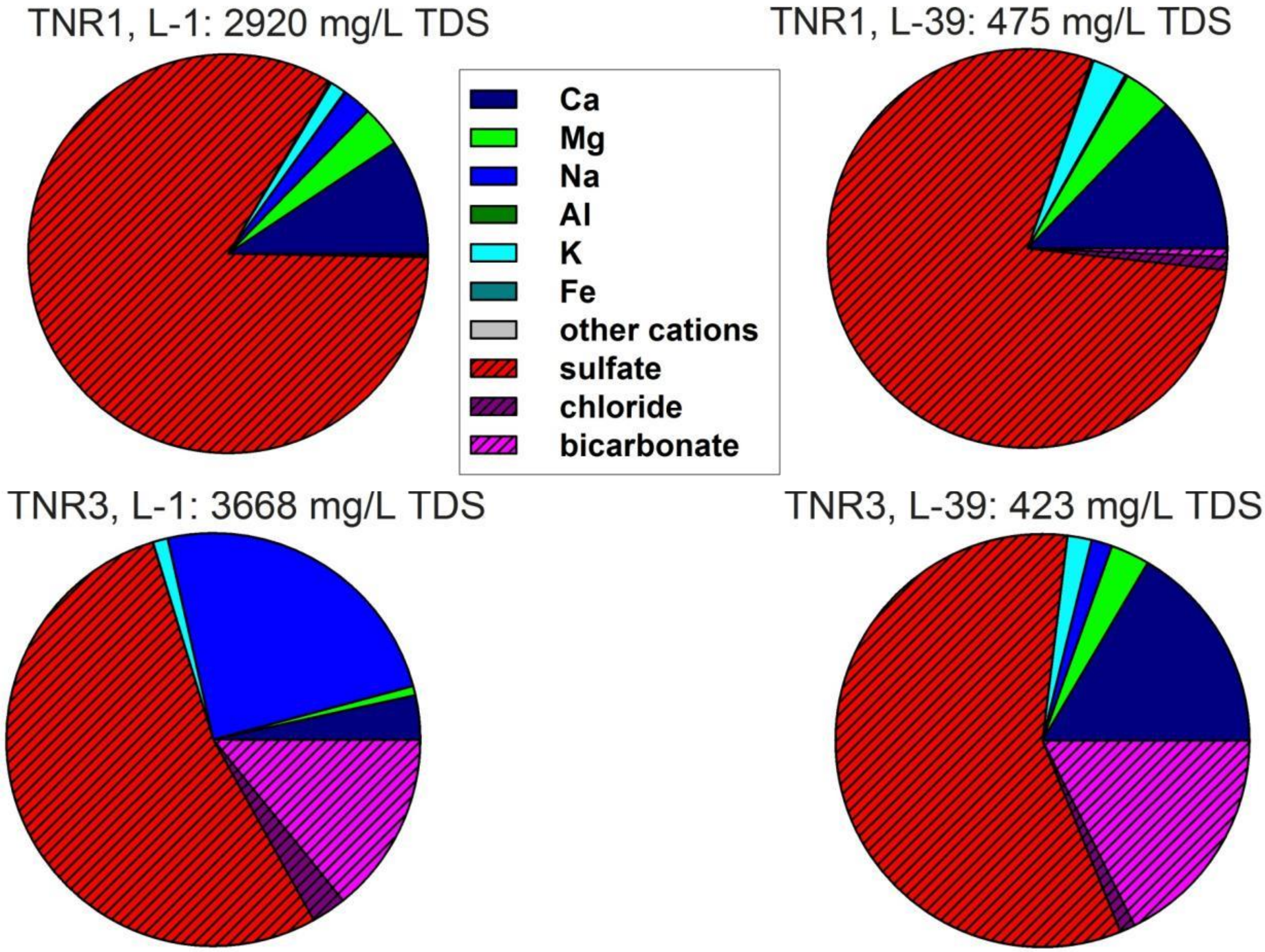


Minimal bicarbonate shift?

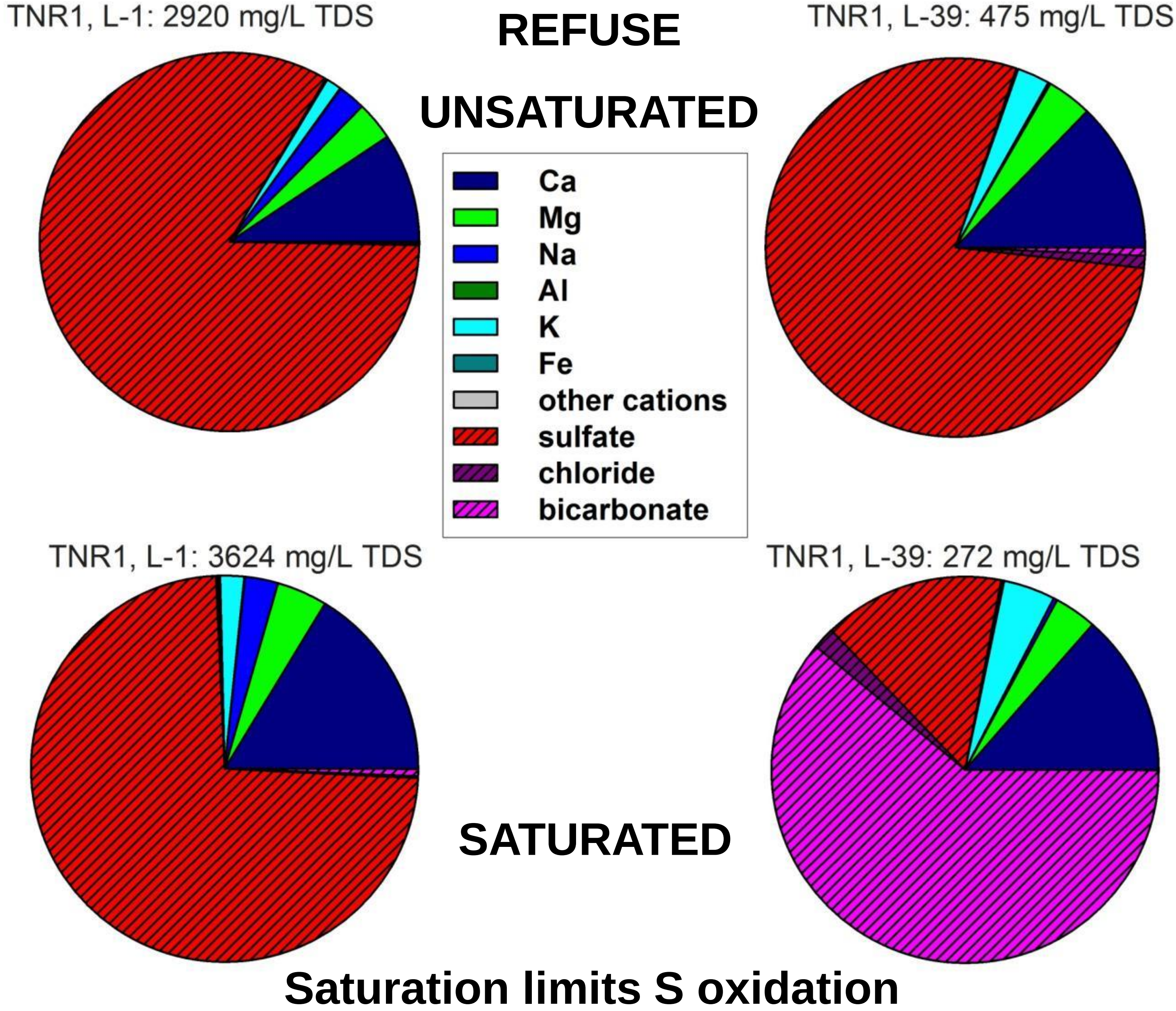
SPOIL (TN3) UNSATURATED vs SATURATED



UNSATURATED REFUSE – TNR1 and TNR3 mass



Continued sulfate release due to S oxidation.



REFUSE
UNSATURATED
TNR1, L-1: 2920 mg/L TDS
TNR1, L-39: 475 mg/L TDS
Ca
Mg
Na
Al
K
Fe
other cations
sulfate
chloride
bicarbonate
TNR1, L-1: 3624 mg/L TDS
TNR1, L-39: 272 mg/L TDS
SATURATED
Saturation limits S oxidation

Summary

- For most spoil and refuse samples (saturated and unsaturated) TDS elution declined rapidly over the first several leach events (approximately 2 – 3 pore volumes), then declined slowly and steadily over the remainder of the study.

- For spoil materials, saturation appeared to affect the pattern of TDS release, but not the overall release of TDS over the study period.

- For 3 of 4 refuse materials, saturation significantly decreased TDS release after the first 6 – 8 leach events.

Summary

- **All 5 spoil samples equilibrated to EC < 500 uS/cm within 5 to 20 leach cycles (approximately 2 – 7 pore volumes).**

- **Unsaturated refuse samples maintained EC > 500 uS/cm over the course of the study.**

  Under saturated conditions, 3 refuse samples equilibrated to EC < 500 uS/cm (within 14 – 18 leach cycles).

Summary

- **Cation composition was dominated by Ca and Mg, with lesser amounts of Al, K, Na and Fe.**
- **Anion composition was dominated by sulfate and bicarbonate, with lesser amounts of chloride.**
- **Mass release for most elements reflected declining EC levels (exceptions included bicarbonate and some trace metals).**
- **For most spoil samples, sulfate was initially the dominant anion, but over time bicarbonate became the dominant anion.**

Acknowledgements

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