Lithium – Prevalence and Implications for Kansas' Drinking Water Supplies

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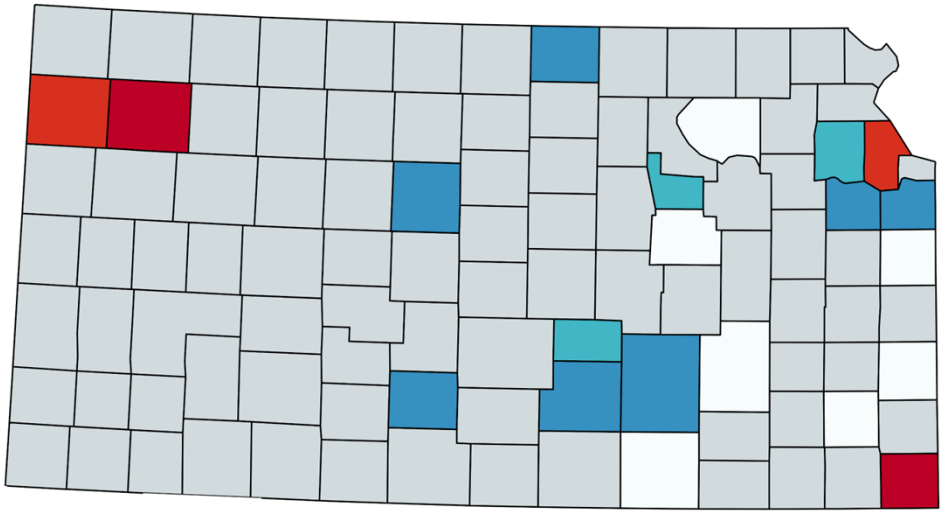
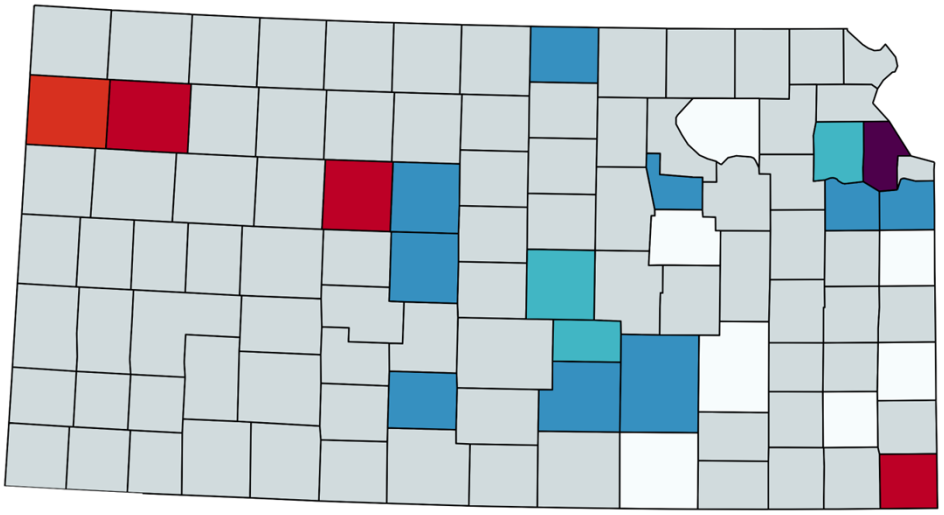
December 2023



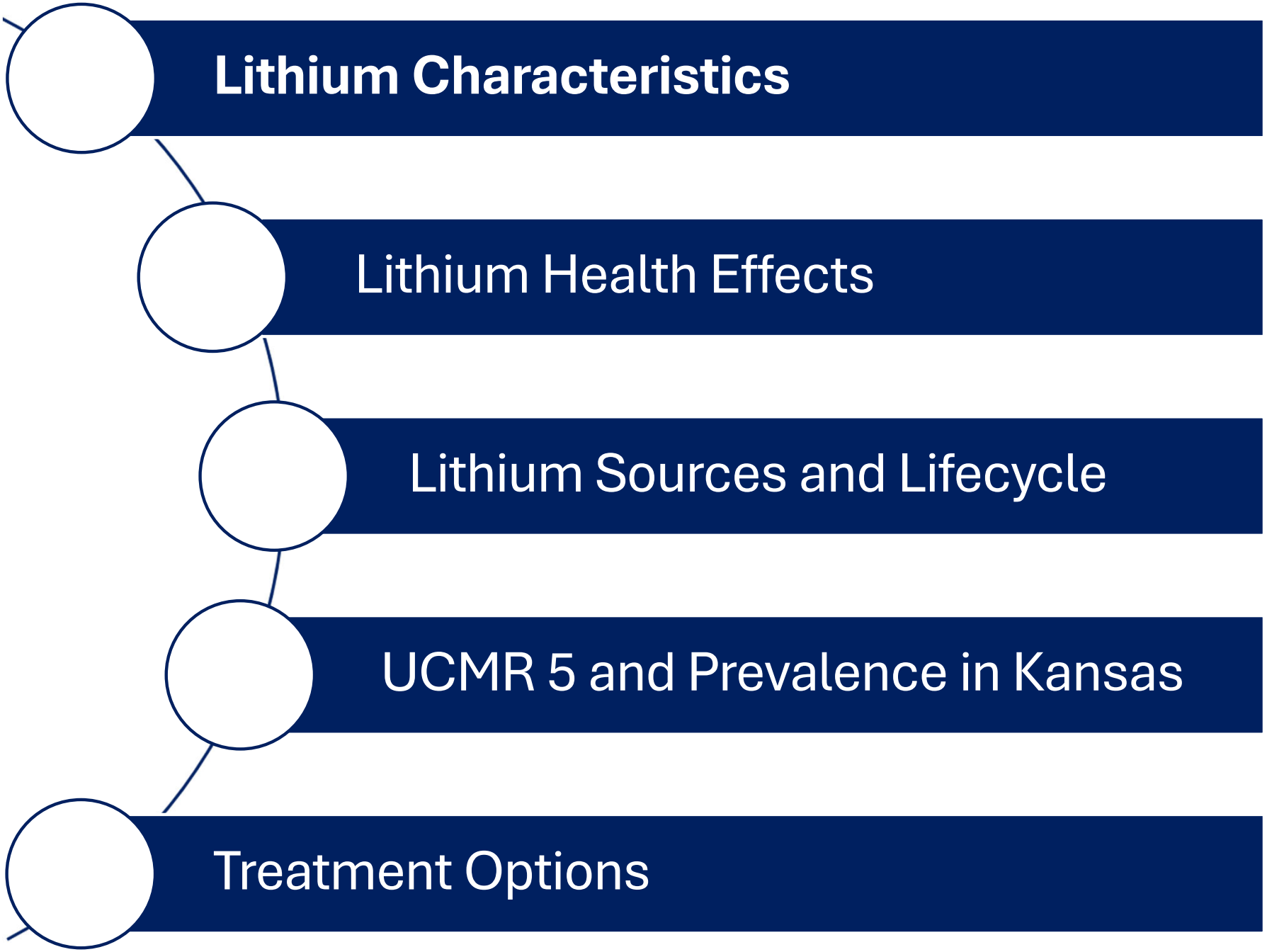
April 2024



Outline

- Lithium Characteristics
- Lithium Health Effects
- Lithium Sources and Lifecycle
- UCMR 5 and Prevalence in Kansas
- Treatment Options

Outline


Lithium Characteristics
Lithium Health Effects
Lithium Sources and Lifecycle
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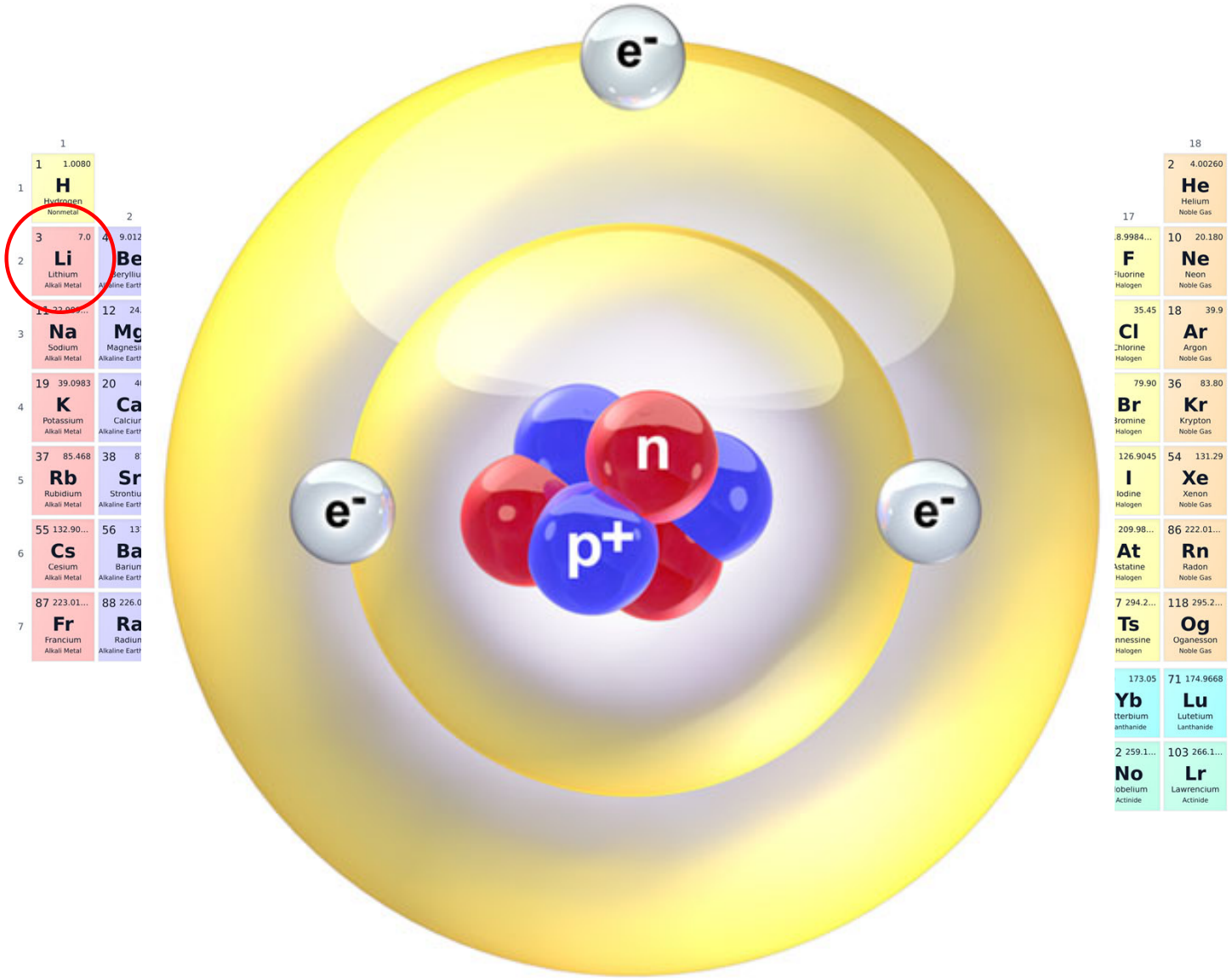
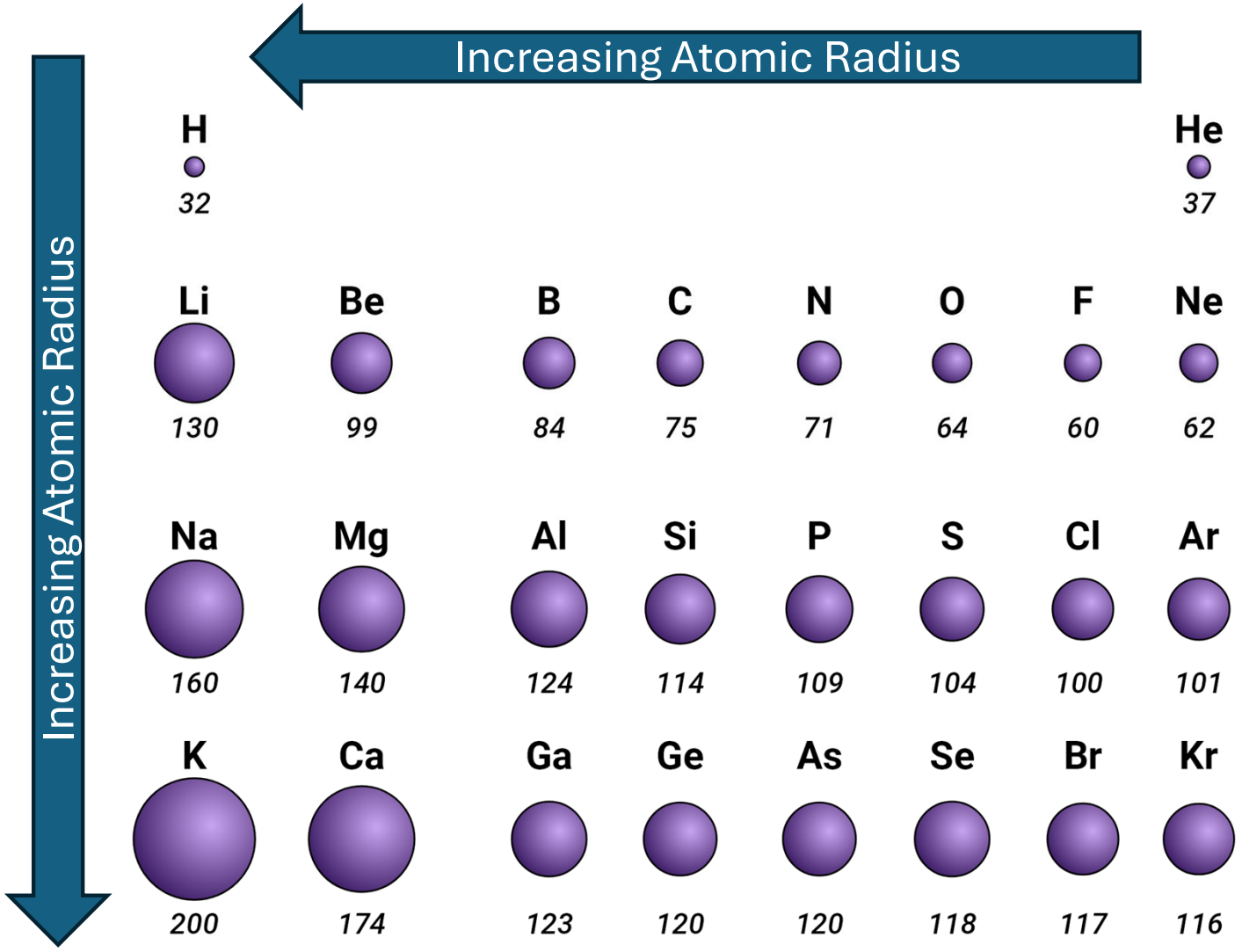
Lithium is the smallest alkali metal.



However, due to the number of protons, lithium's atomic radius is similar to magnesium



Elemental lithium is very reactive with water and forms hydrogen.

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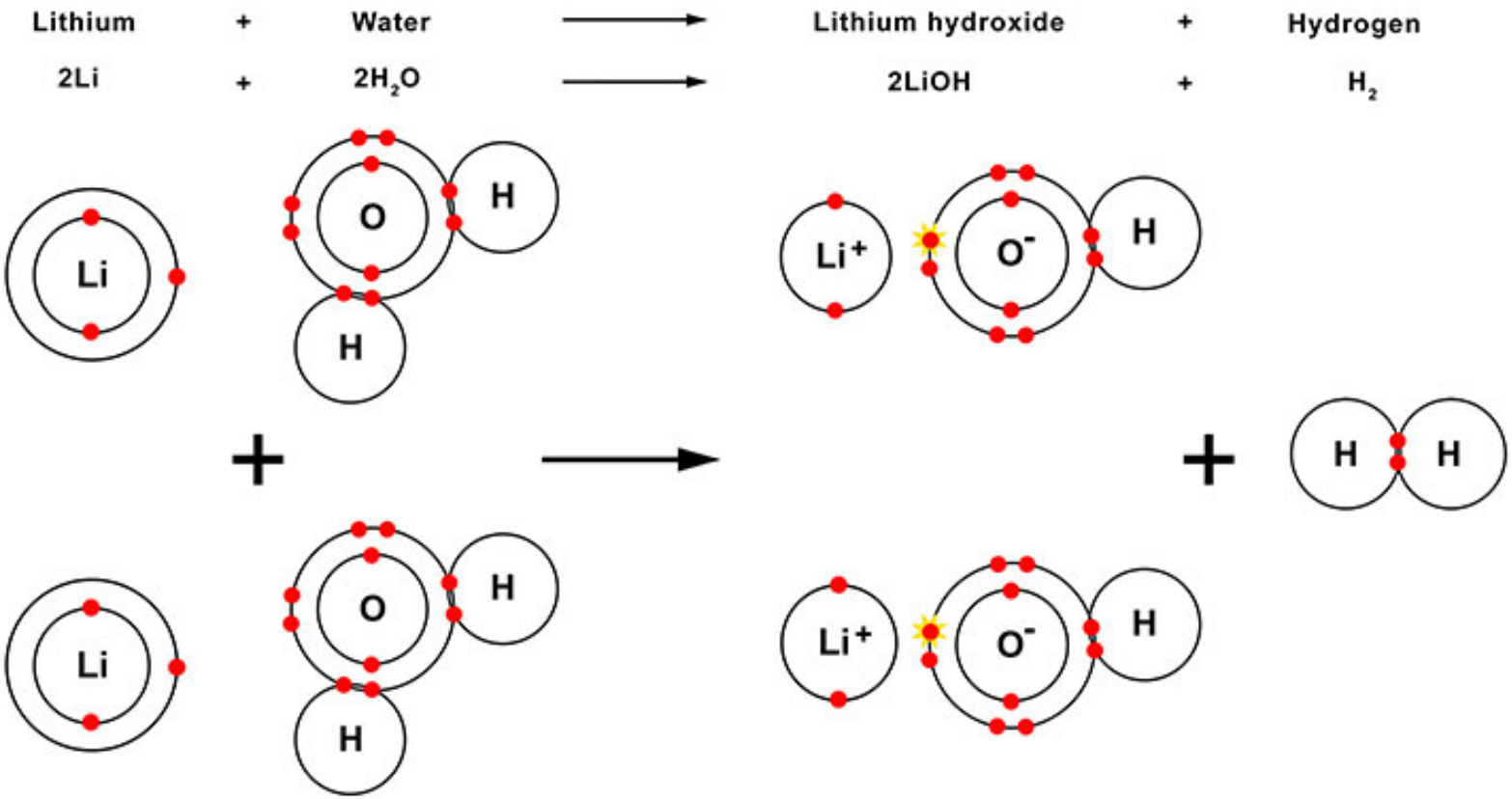
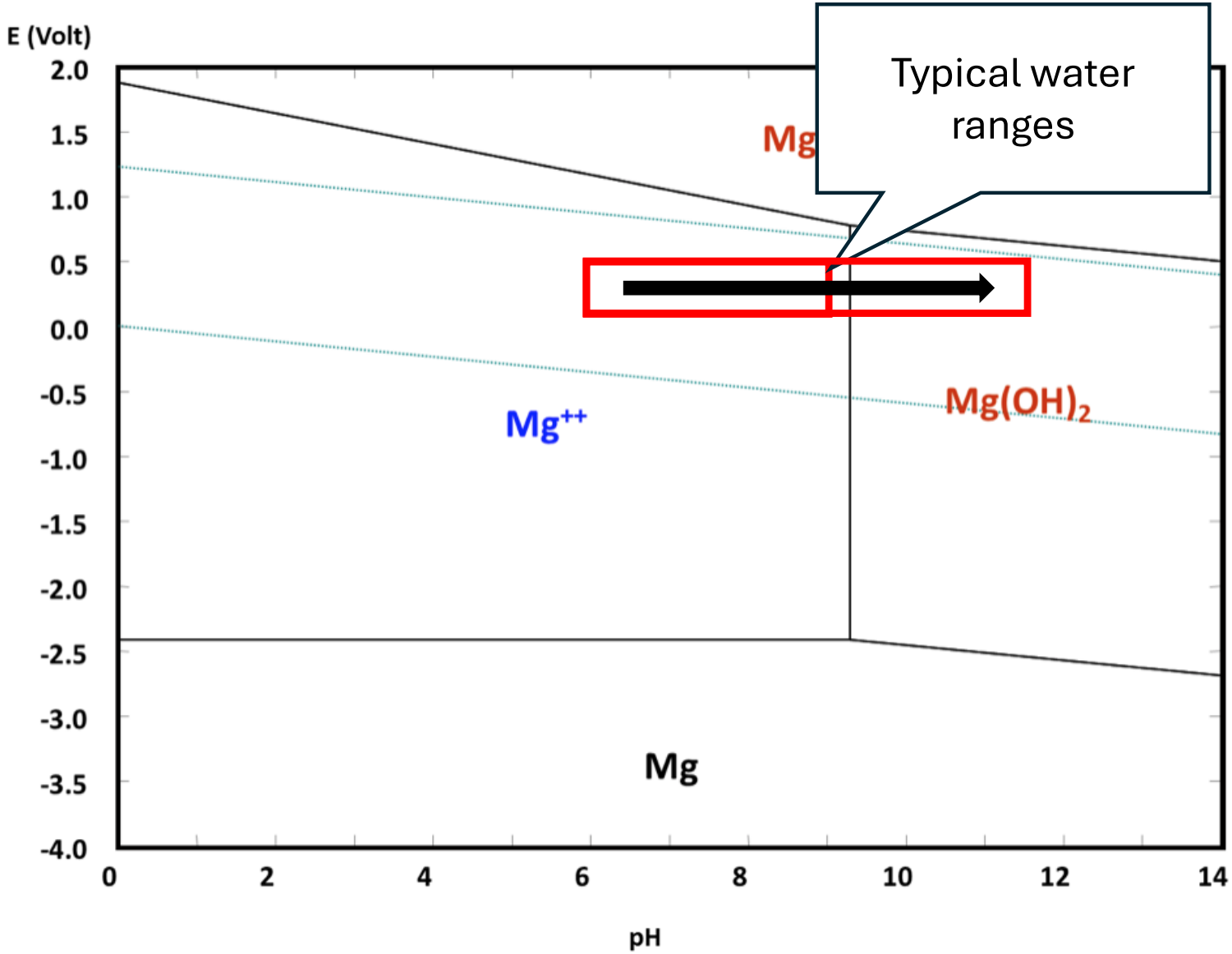
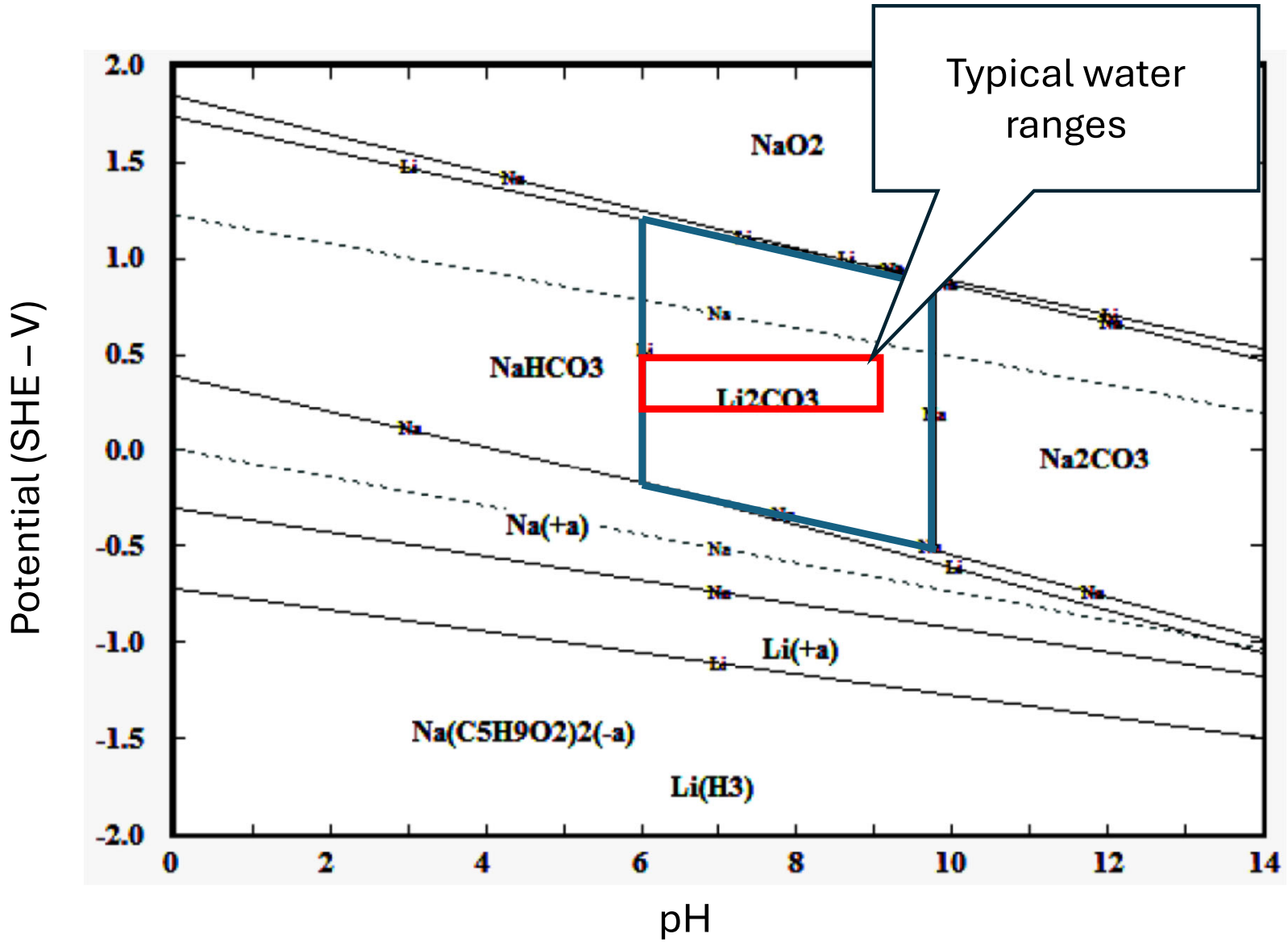


Pourbaix diagrams provide insight into solubility and precipitation of contaminants in water.

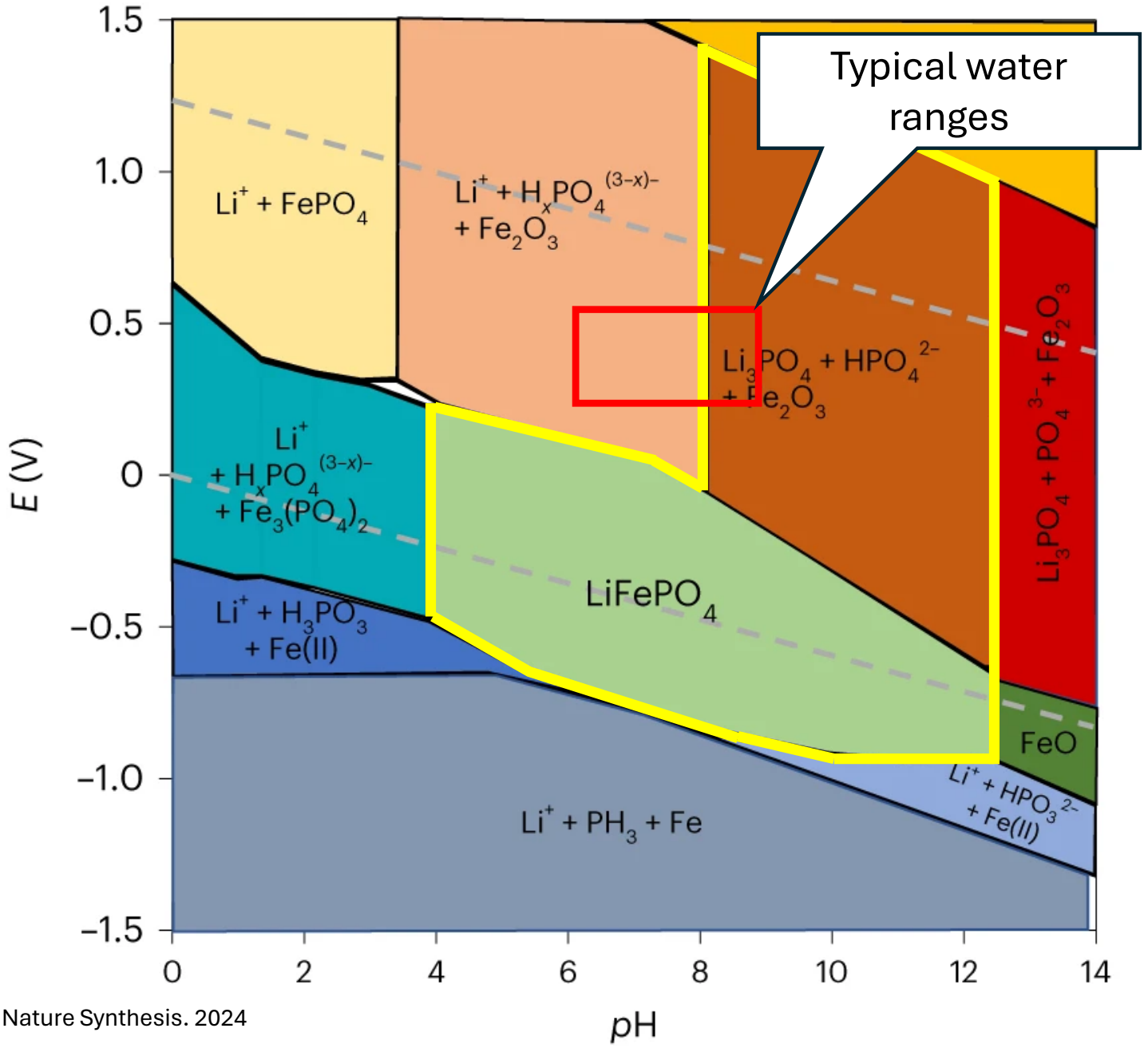


Pourbaix diagrams provide insight into solubility and precipitation potential of lithium from water.



Anderson. Technical Report – Hydrometallurgical recovery of materials from lithium-ion batteries. 2023

Another treatment combination with iron and phosphate may also yield insoluble products



 Wang. Nature Synthesis. 2024

However, the solubility must be considered when low final concentrations are required.

- The solubility constant establishes the relationship between the dissolved species and the solid.

$$K_{sp} = [A^+]^a [B^-]^b$$

- K_{sp} = solubility product constant
- A^+ = cation in an aquious solution
- B^- = anion in an aqueous solution
- a, b = relative charge of A and B

However, the solubility must be considered when low final concentrations are required.

- K_{sp} of common water constituents include:
  - Magnesium Hydroxide ~5.6×10^{-12}
  - Calcium Carbonate ~2.8×10^{-9}
  - Iron Hydroxide ~4×10^{-34}
- In contrast, lithium is more soluble:
  - Lithium carbonate ~2.5×10^{-2}
  - Lithium phosphate ~3.2×10^{-9}

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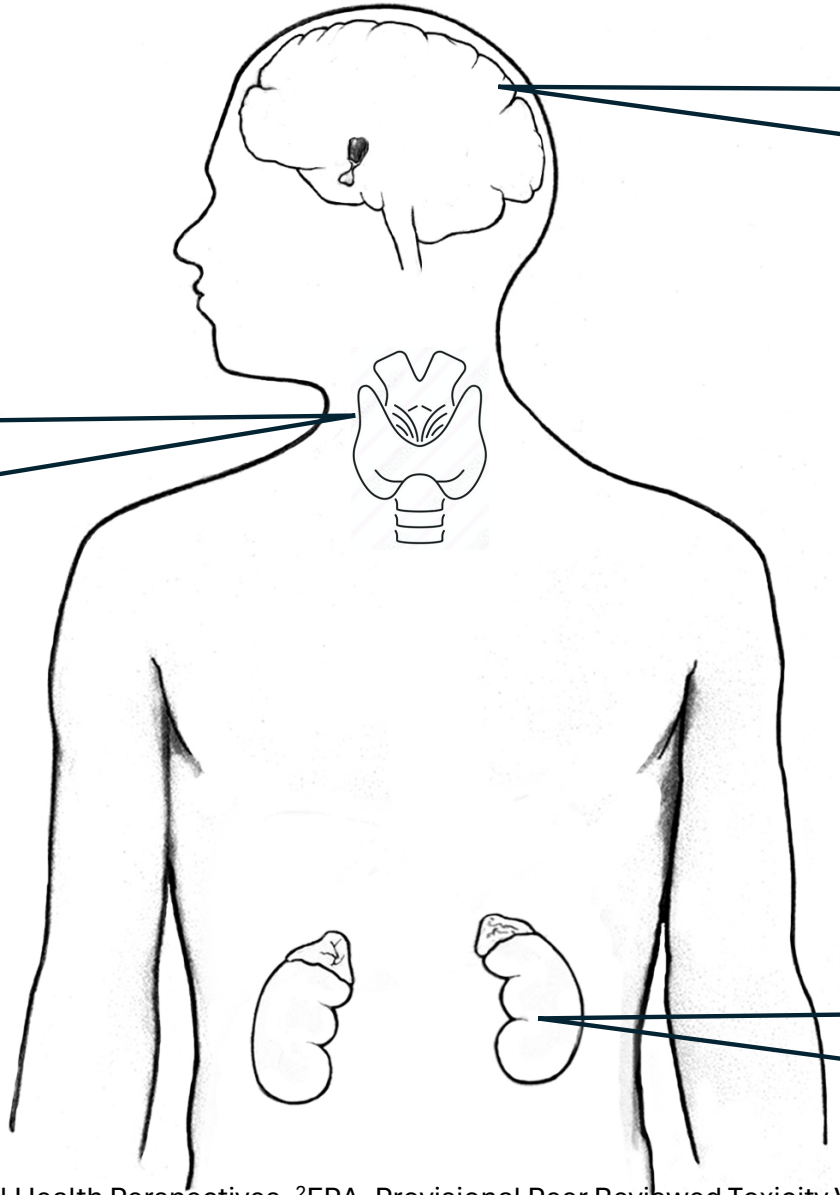
Lithium health impact information is limited; however, reports note impacts on brain, thyroid, and kidneys.



Several studies on the impact of mental health

Negative Correlation with Free Thyroxine[1]

Diuretic effect on kidneys[2]

[1]Broberg. 2011. Environmental Health Perspectives. [2]EPA. Provisional Peer Reviewed Toxicity Values for Lithium. 2008

Lithium health impact information is limited; however, reports note impacts on brain, thyroid, and kidneys.

Concentration ($\mu g\ L^{-1}$)	Human health consequences
2–27	Long-term increased Li exposure in drinking water may be associated with a **lower incidence of dementia in a nonlinear way**. However, other confounding factors associated with municipality of residence cannot be excluded.
0–40	High Li concentration in drinking water **has no association with dementia.**
1–39	Effect of Li intake through drinking water was associated with a **lower incidence of suicide in a nonlinear way.**
0.1–121	Higher Li in drinking water was associated with **lower suicide rate.**
0–130	Li in drinking water may be associated with a **low risk of male suicide in the general population**. No association was observed in females.
<0–121	Li level in drinking water had **no correlation with suicide mortality rate**.
0–12.9	Li in drinking water **might have a protective effect on the risk of suicide among females**. But no association was found in men.
117–14343	Long term Li exposure via drinking water was **associated with thyroid function and thyroid stimulating hormone**.

The EPA UCMR reporting requirement is 9 µg L^{-1}.

- The reporting requirement was determined by the lowest observed adverse effects level of 2.1 mg kg^{-1} day^{-1}.
- The adverse effect level was further adjusted based on three uncertainty factors.
  - /10 – extrapolate from the lowest observed adverse effect level to the no observed effect level.
  - /10 – protect sensitive subpopulations
  - /10 – uncertainty in data availability for human health impacts.

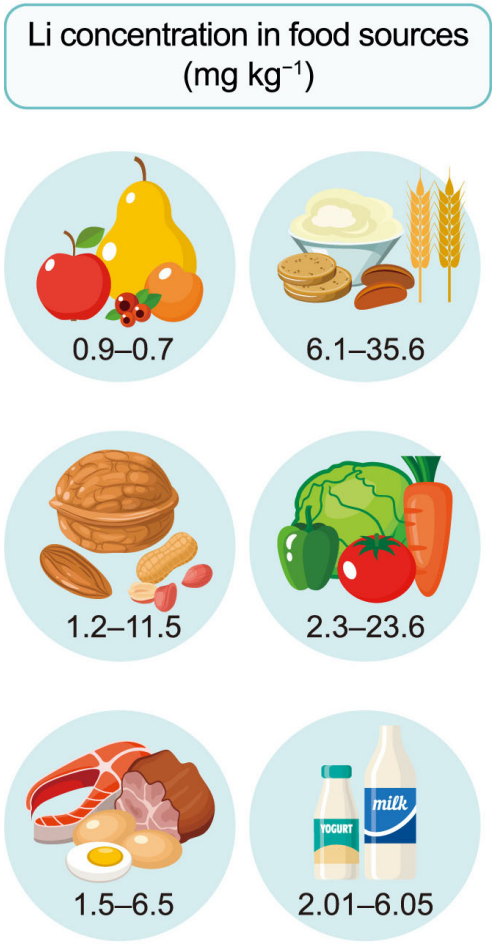
$$2.1 \frac{mg}{kg * day} \div 10 \div 10 \div 10 = 2 \frac{\mu g}{kg * day}$$

The Health Based Screening Level (HBSL) includes exposure to contaminants in other sources.

$$2\ \frac{\mu g}{kg * day} *$$

$$= 140\ \frac{\mu g}{day}$$

-

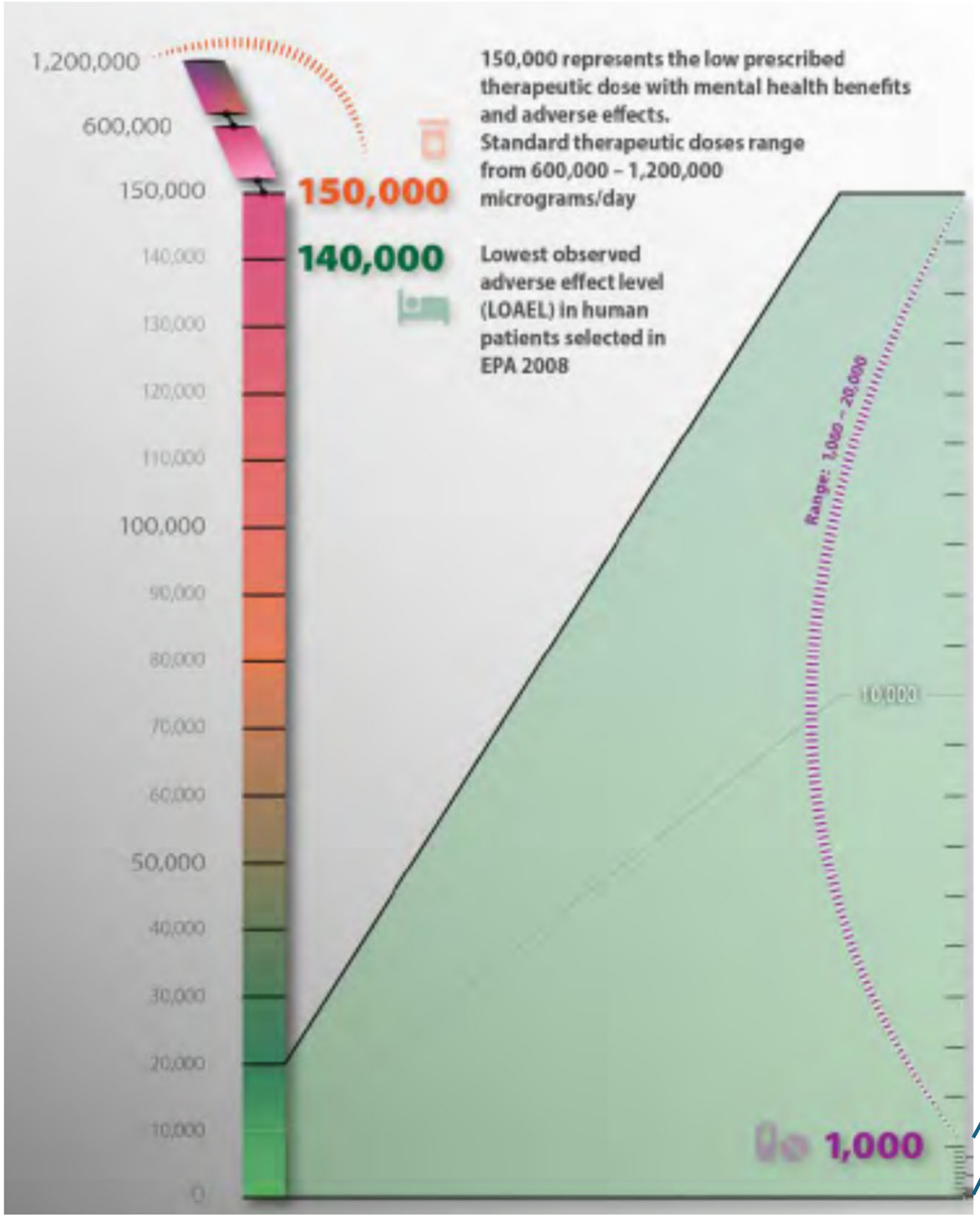


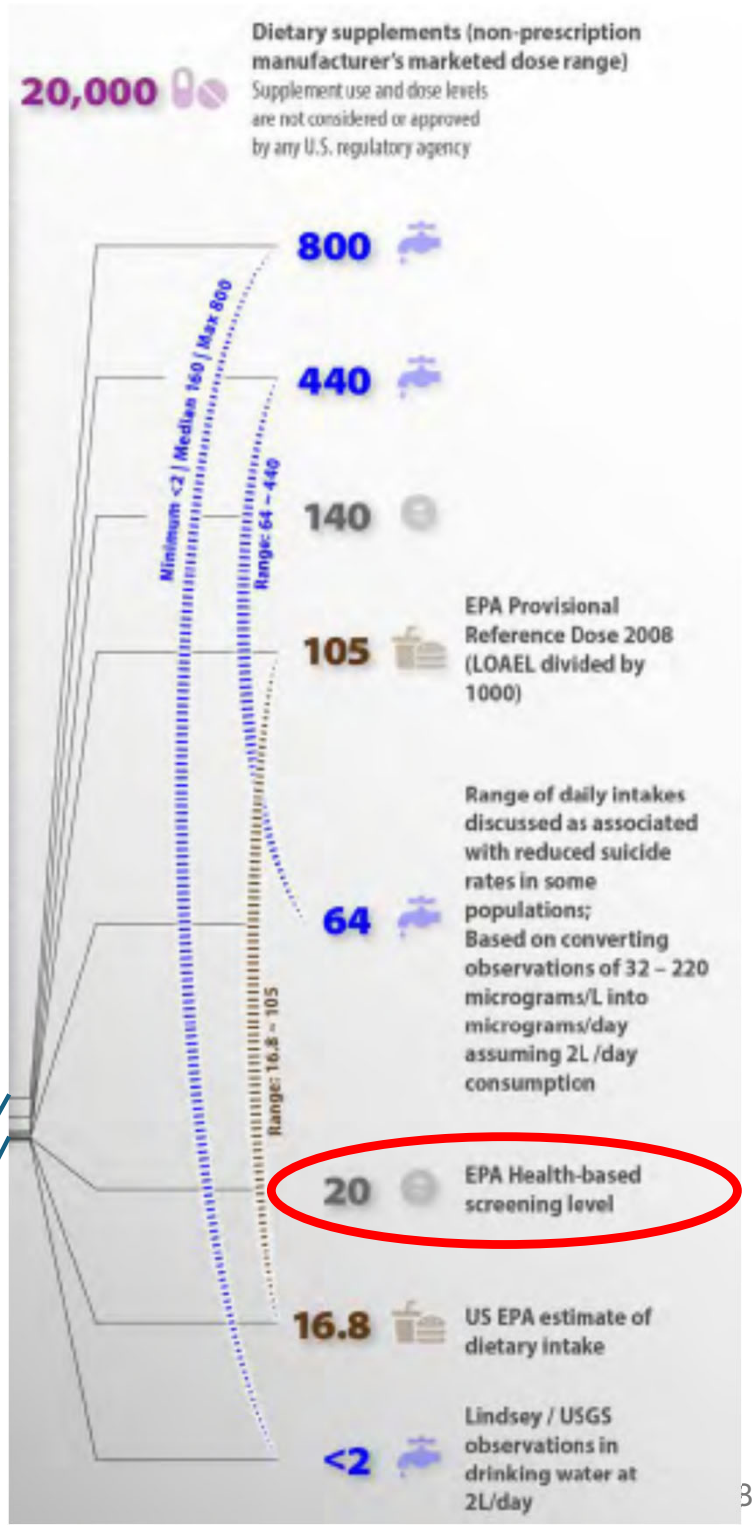
$$= 10\ \frac{\mu g}{L}$$

$$= 60\ \frac{\mu g}{L}$$

if water is the only source of lithium

 Shakoor. Environmental Science and Ecotechnology. 2023.


1,200,000
600,000
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
150,000
140,000
150,000 represents the low prescribed therapeutic dose with mental health benefits and adverse effects.
Standard therapeutic doses range from 600,000 – 1,200,000 micrograms/day
Lowest observed adverse effect level (LOAEL) in human patients selected in EPA 2008
Range: 1,000 – 20,000
10,000
1,000


20,000
Dietary supplements (non-prescription manufacturer's marketed dose range)
Supplement use and dose levels are not considered or approved by any U.S. regulatory agency
800
440
140
105
EPA Provisional Reference Dose 2008 (LOAEL divided by 1000)
Minimum <2 | Median 160 | Max 800
Range: 64 – 440
Range: 16.8 – 105
64
Range of daily intakes discussed as associated with reduced suicide rates in some populations;
Based on converting observations of 32 – 220 micrograms/L into micrograms/day assuming 2L /day consumption
20
EPA Health-based screening level
16.8
US EPA estimate of dietary intake
<2
Lindsey / USGS observations in drinking water at 2L/day

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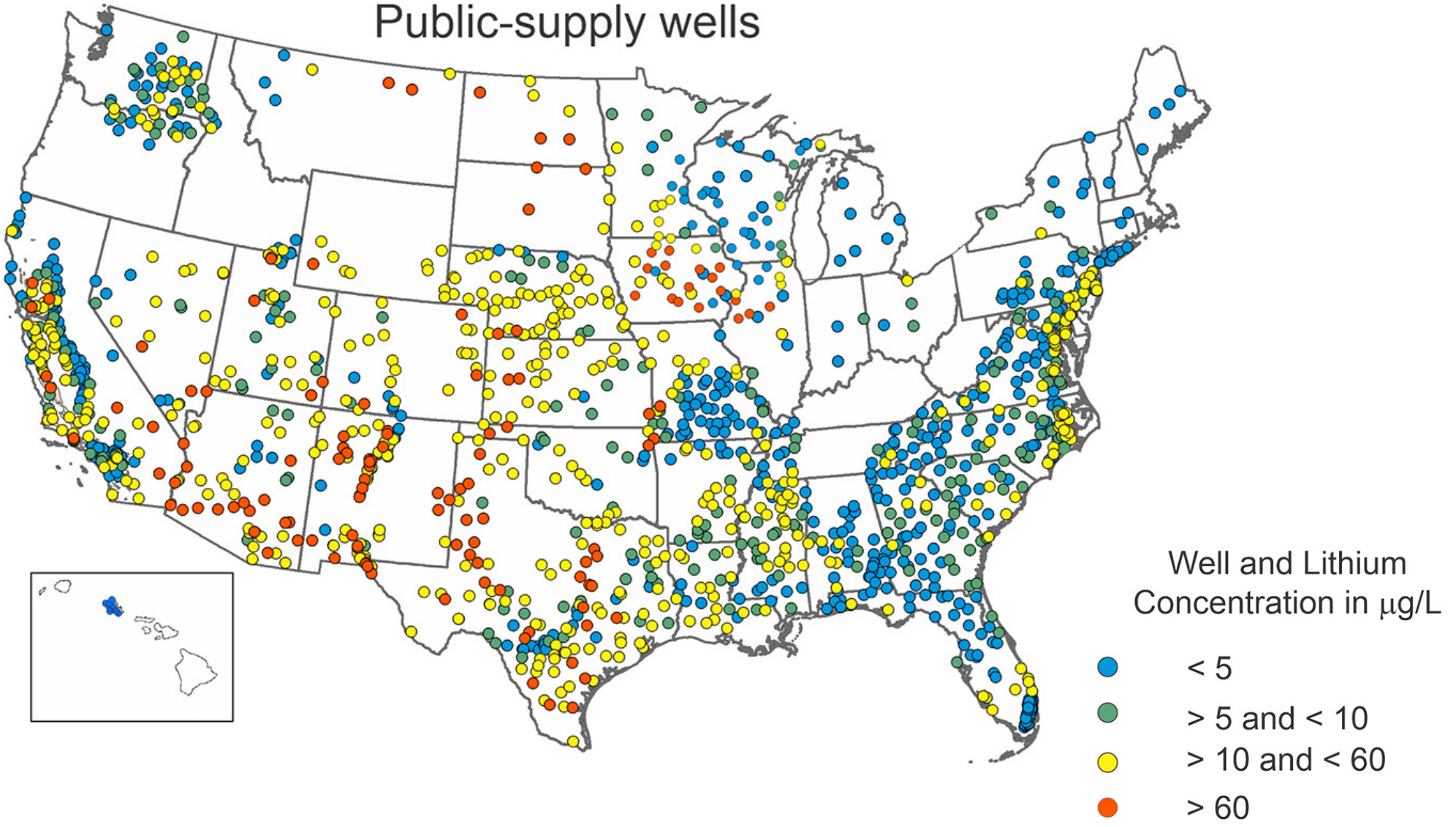
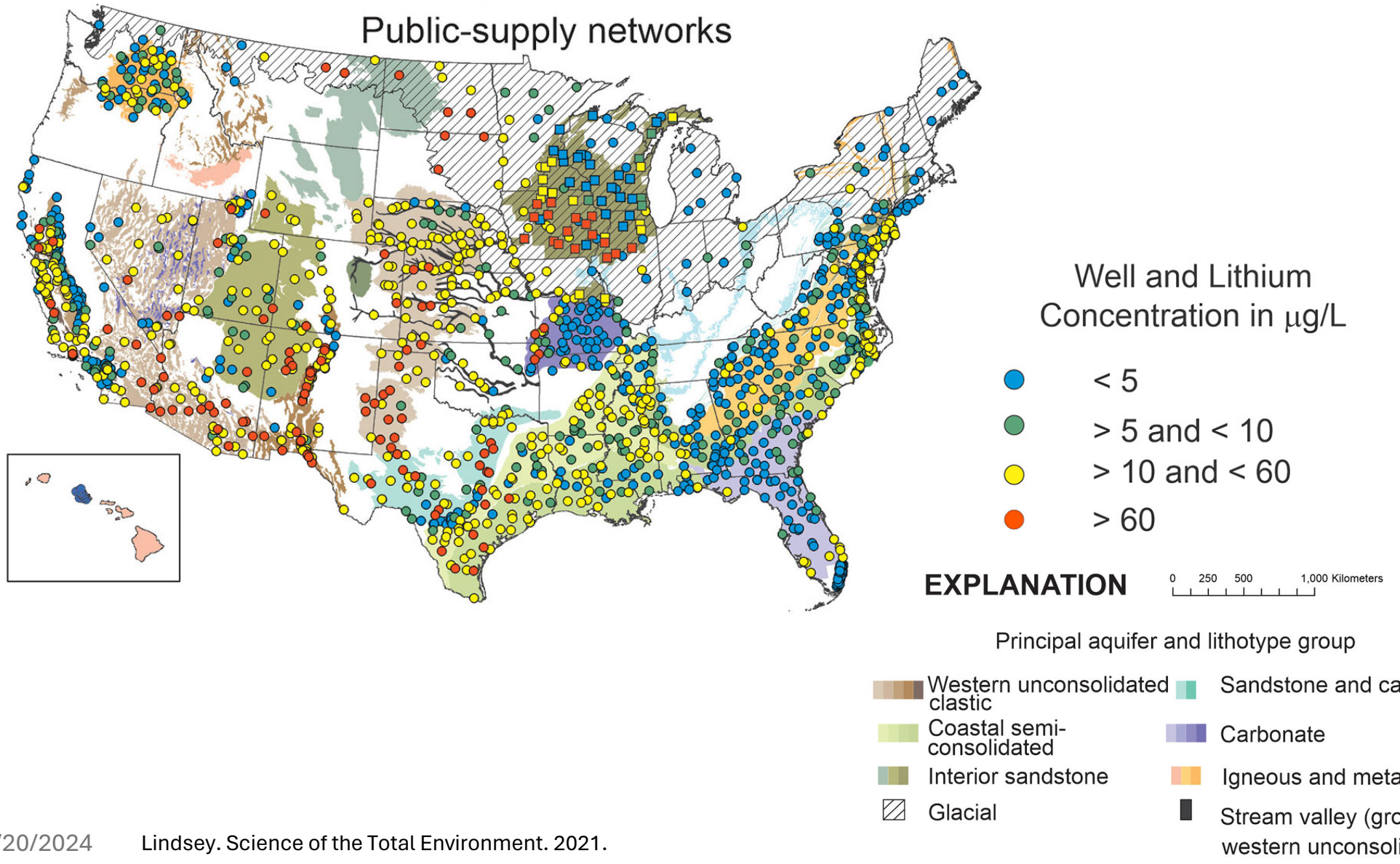
Reevaluation of lithium in water supplies emerged from a 2021 USGS study.



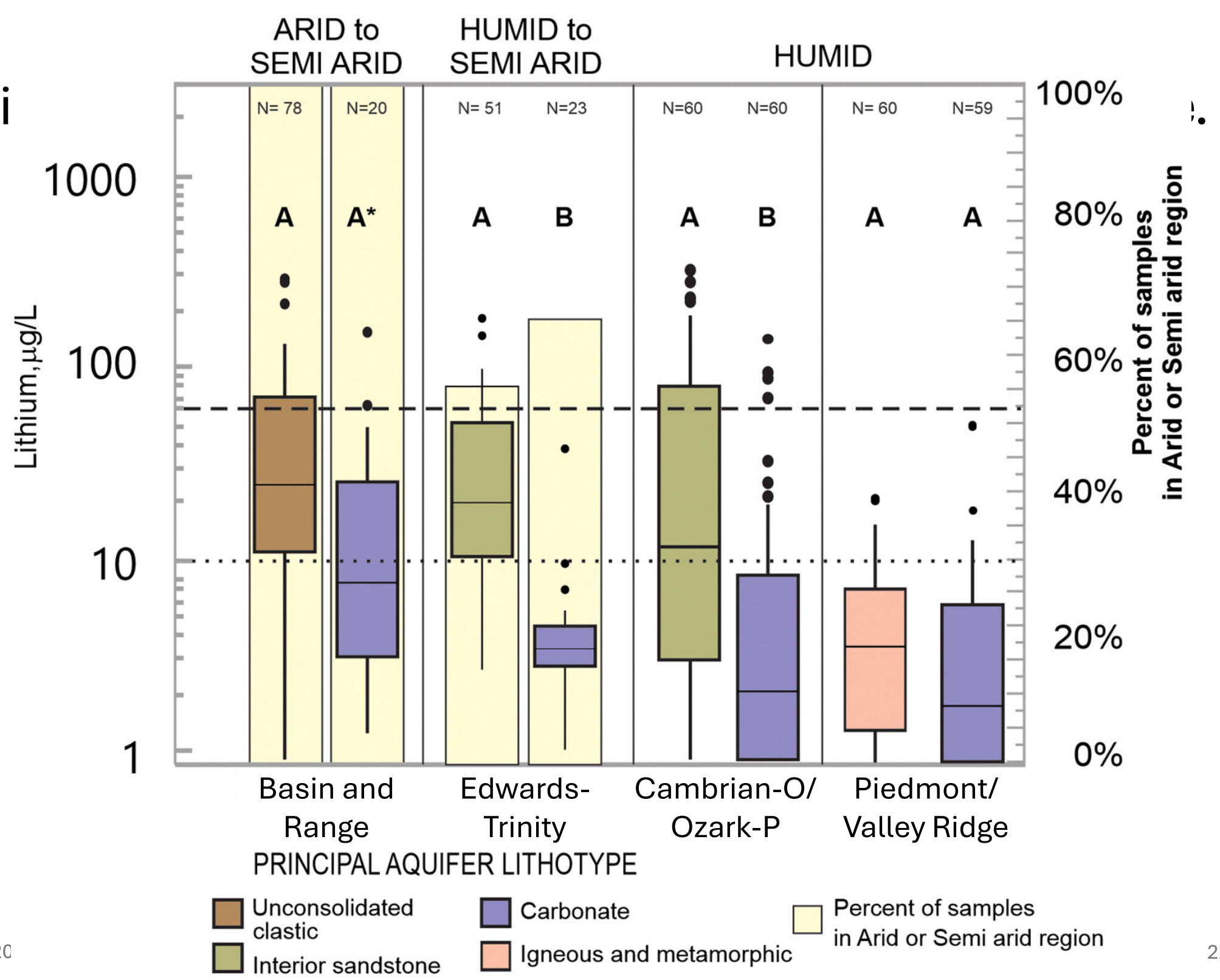
 Lindsey. Science of the Total Environment. 2021.

Lithium trends were found with formation and climate.

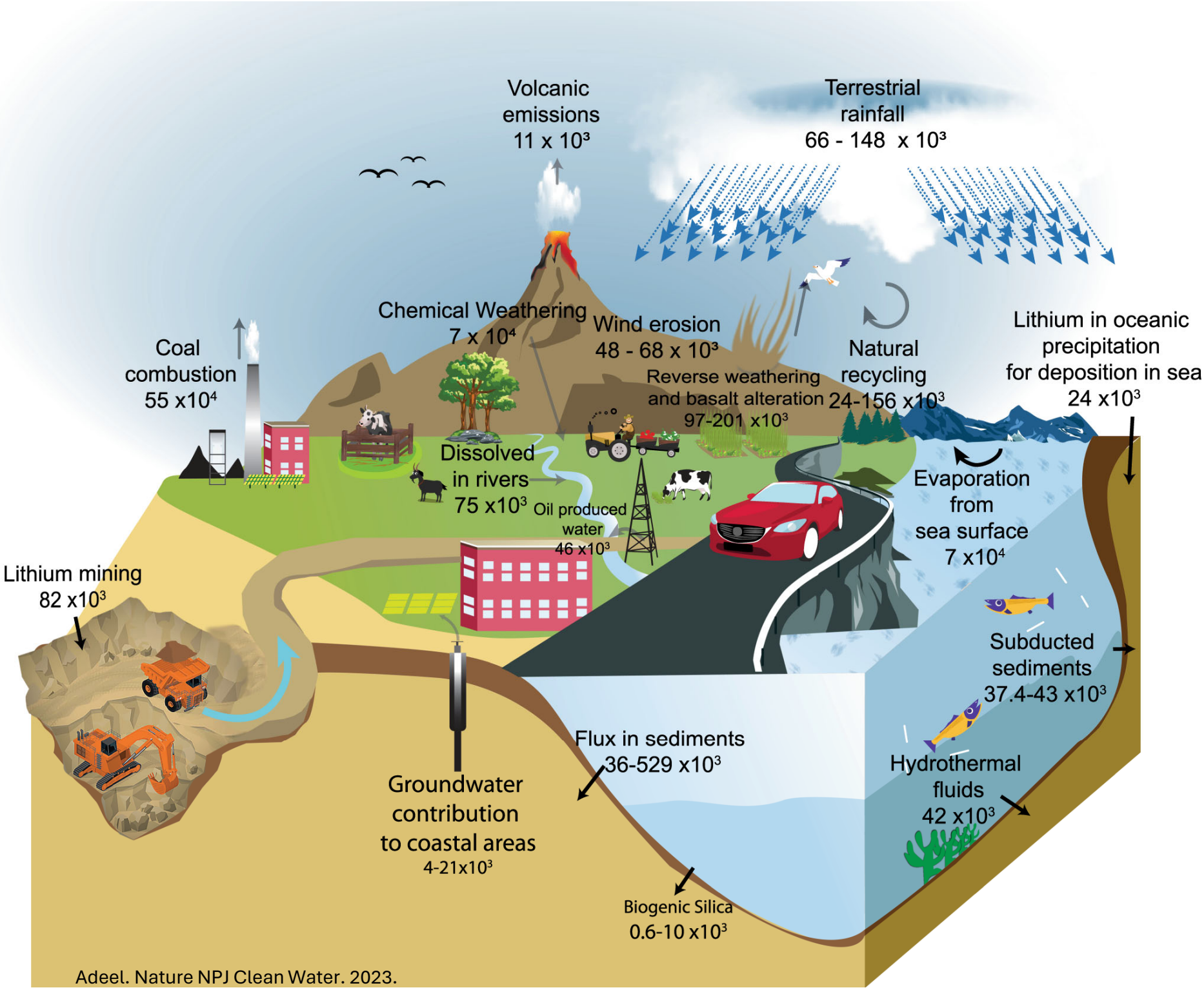


Lindsey. Science of the Total Environment. 2021.

Li

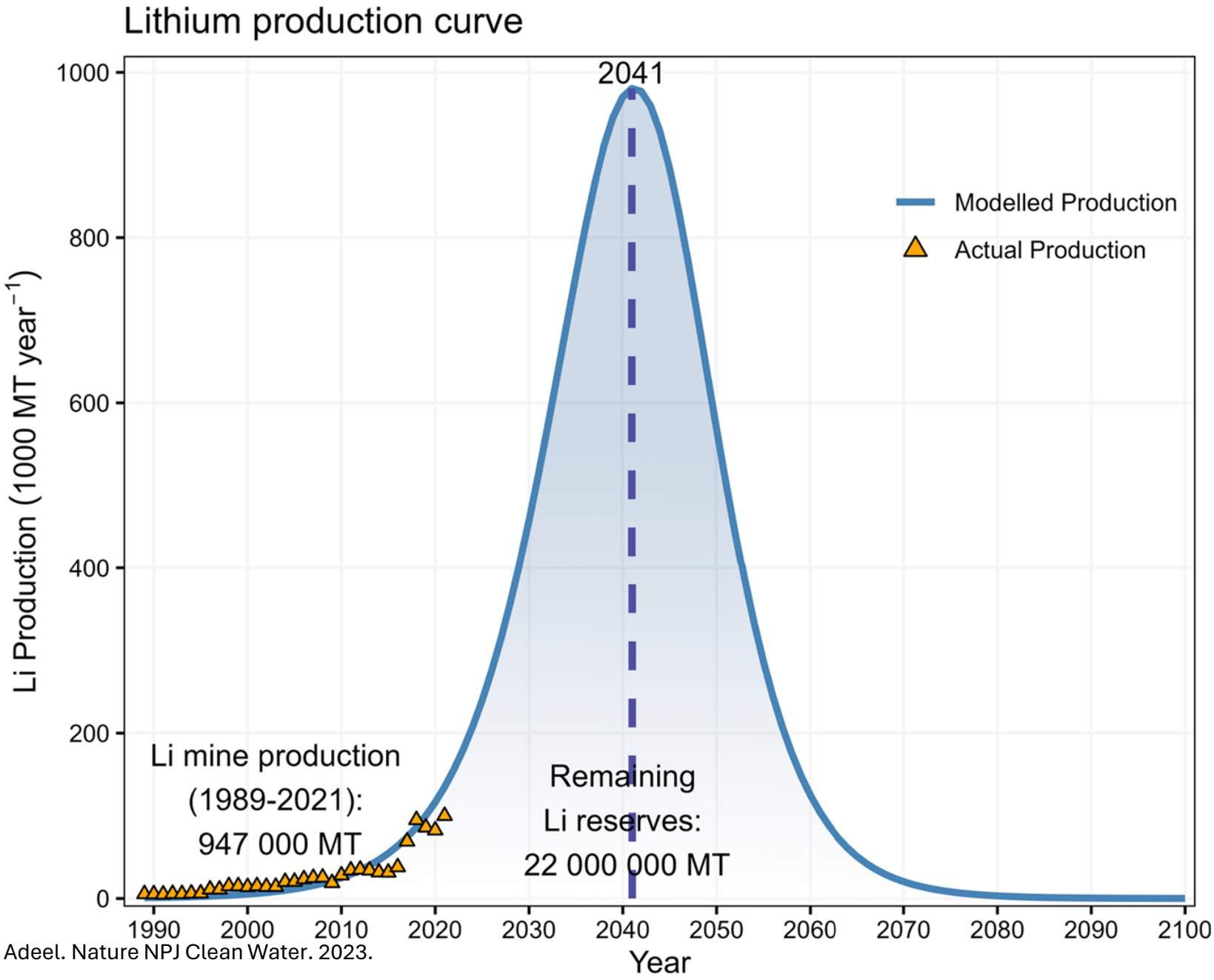

ARID to SEMI ARID
HUMID to SEMI ARID
HUMID
N= 78
N=20
N= 51
N=23
N=60
N=60
N= 60
N=59
A
A*
A
B
A
B
A
A
1000
100
10
1
Lithium, µg/L
100%
80%
60%
40%
20%
0%
Percent of samples in Arid or Semi arid region
Basin and Range
Edwards-Trinity
Cambrian-O/ Ozark-P
Piedmont/ Valley Ridge
PRINCIPAL AQUIFER LITHOTYPE
Unconsolidated clastic
Interior sandstone
Carbonate
Igneous and metamorphic
Percent of samples in Arid or Semi arid region

Li
pc



Adeel. Nature NPJ Clean Water. 2023.

Modeled lithium production is expected to increase and peak in 2041.



Adeel. Nature NPJ Clean Water. 2023.

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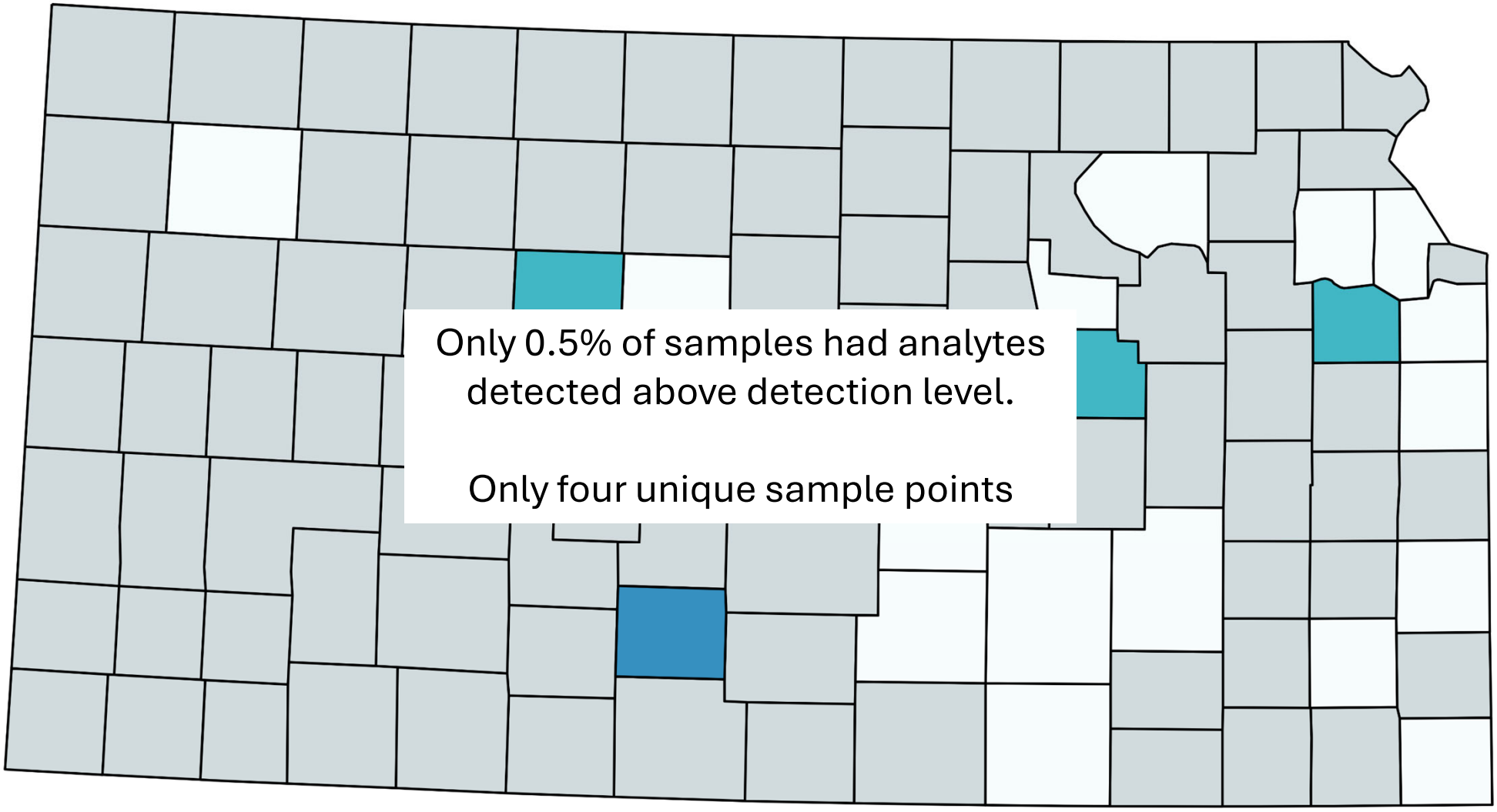
Lithium was included in UCMR 5 and measured using EPA Method 200.7.

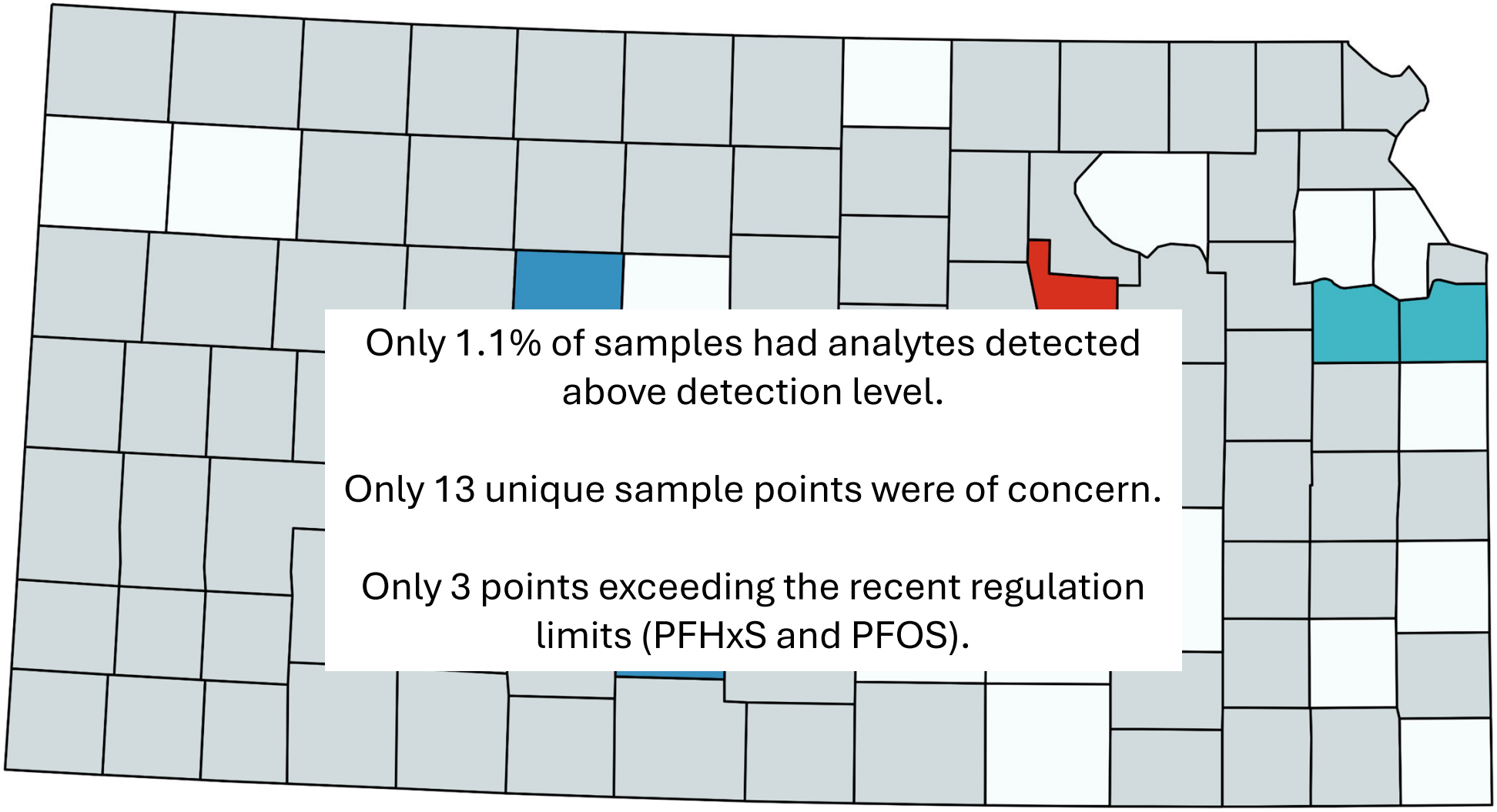
- Lithium was the only non-PFAS compound listed in UCMR 5 (1 of 30).
- EPA Method 200.7 common technique to measure a range of metal contaminants.
- Sa
- Me
  opt
- Sample >9 µg L⁻¹ were reported.

2022	2023	2024	2025	2026
Pre-sampling activities.	Sampling Period (ongoing sample collection, laboratory analysis, and reporting			Post-Sampling Activities (resampling, laboratory analysis, complete upload of data)

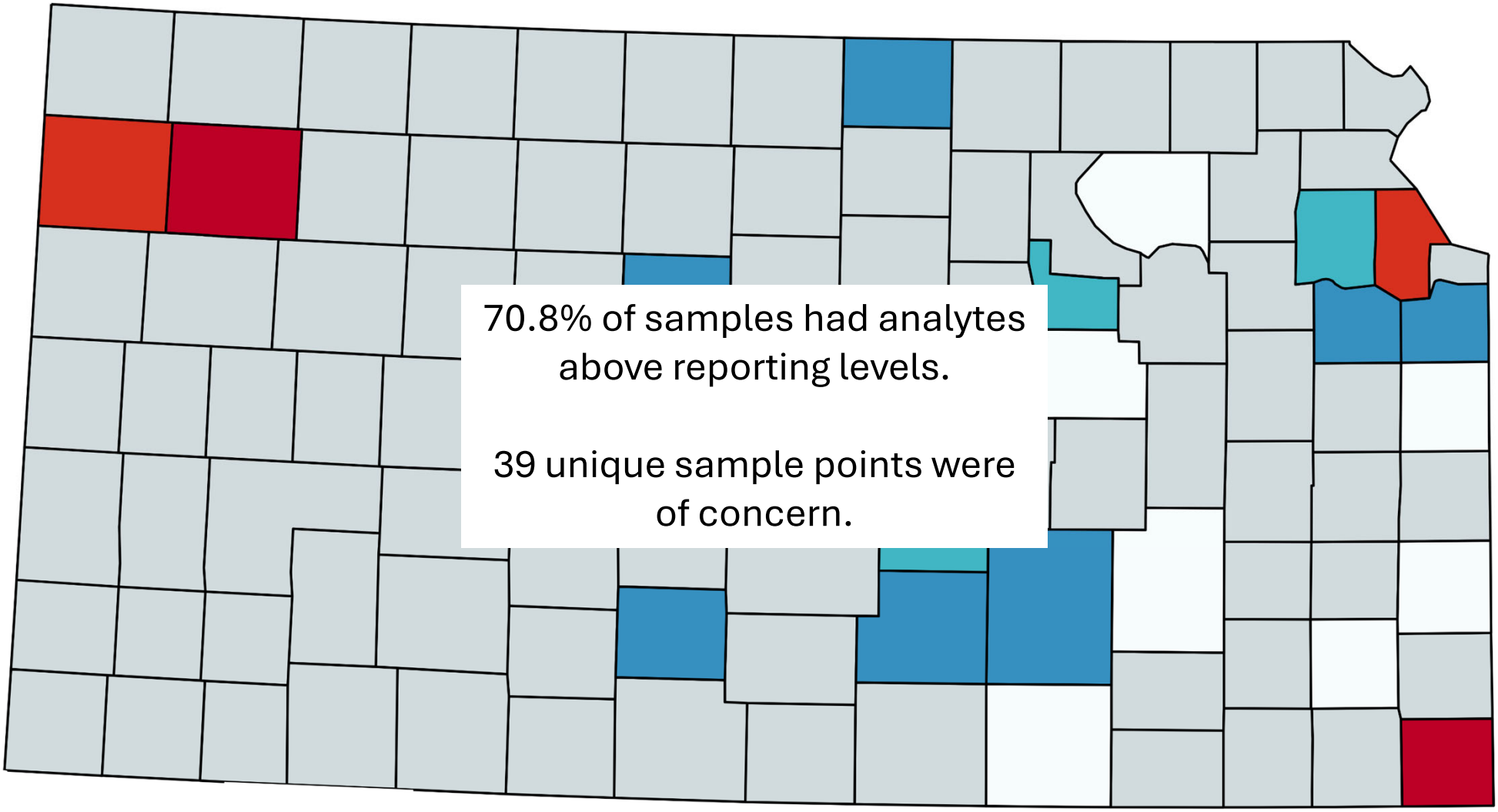
To provide context, here PFAS prevalence in Kansas from December 2023 UCMR5.



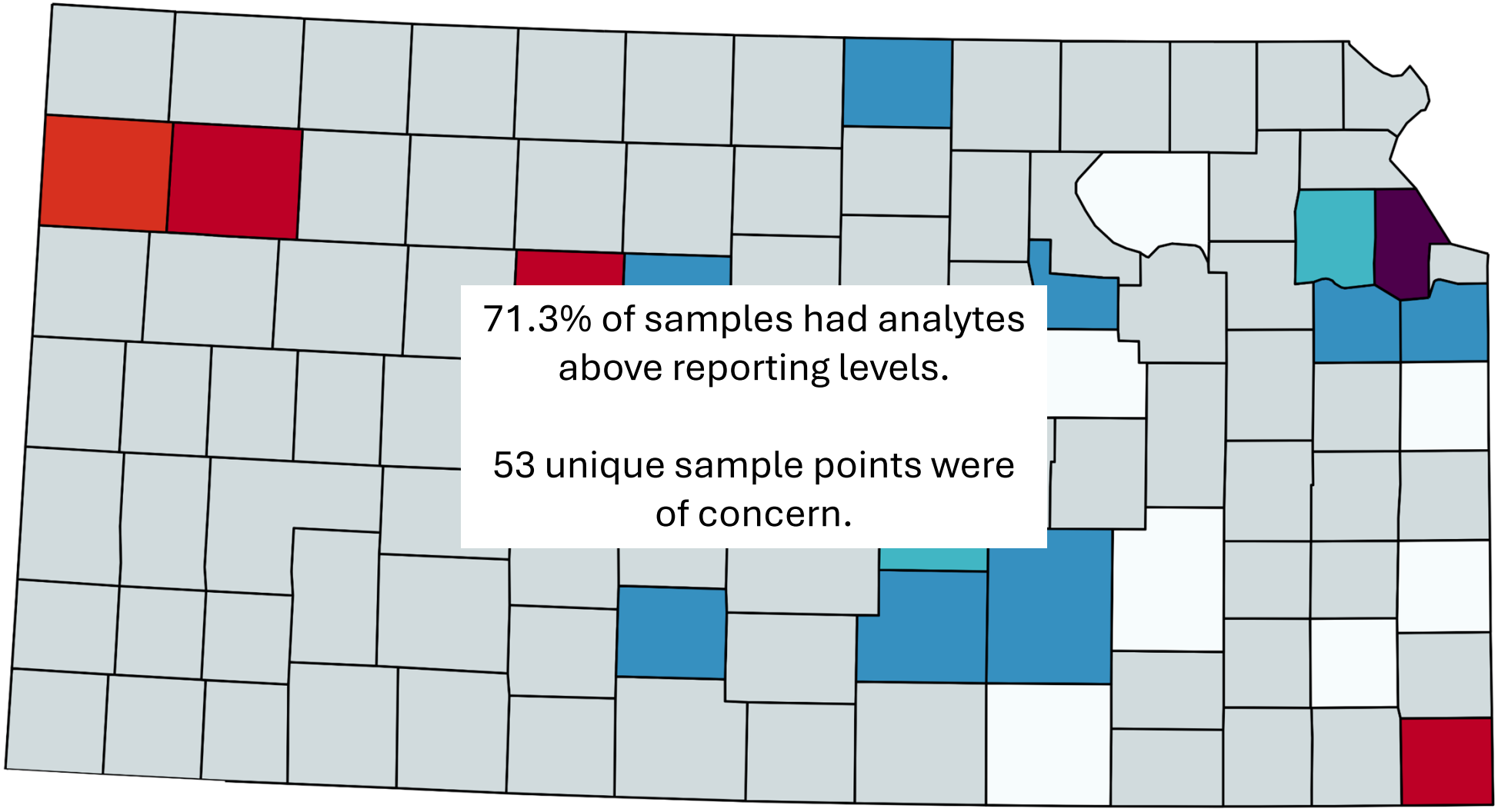
Comparted to PFAS prevalence in Kansas from April 2024 UCMR5.



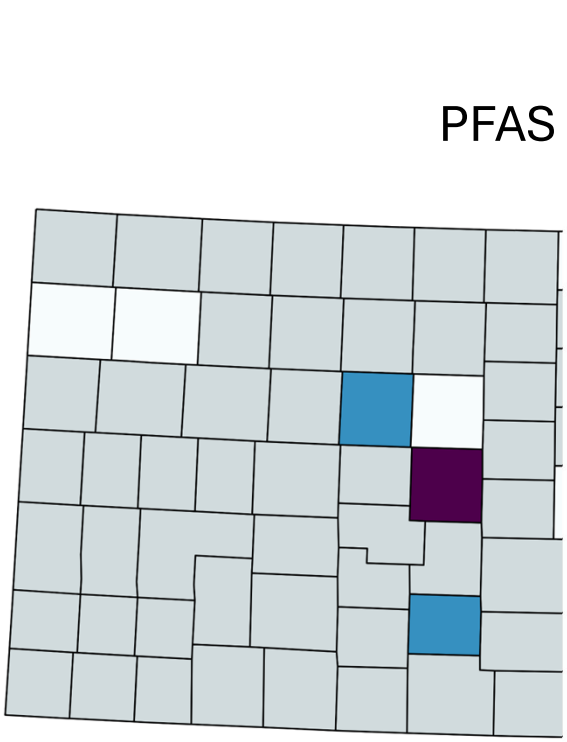
Lithium has more prevalence in Kansas counties from December 2023 UCMR5.



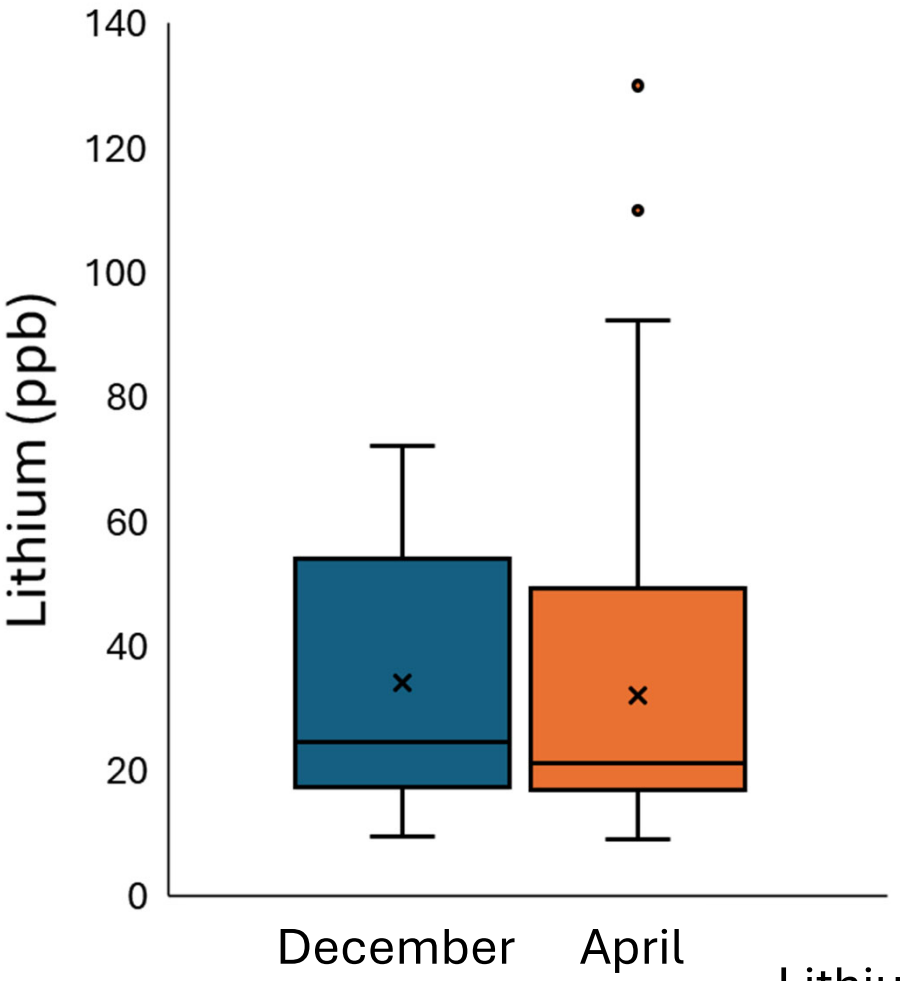
Comparted to Lithium prevalence in Kansas from April 2024 UCMR5.

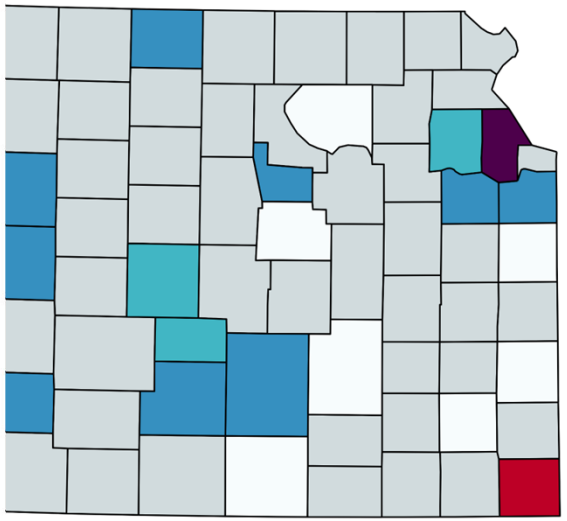


A side-by-side comparison shows a higher prevalence of lithium.



PFAS





.ithium

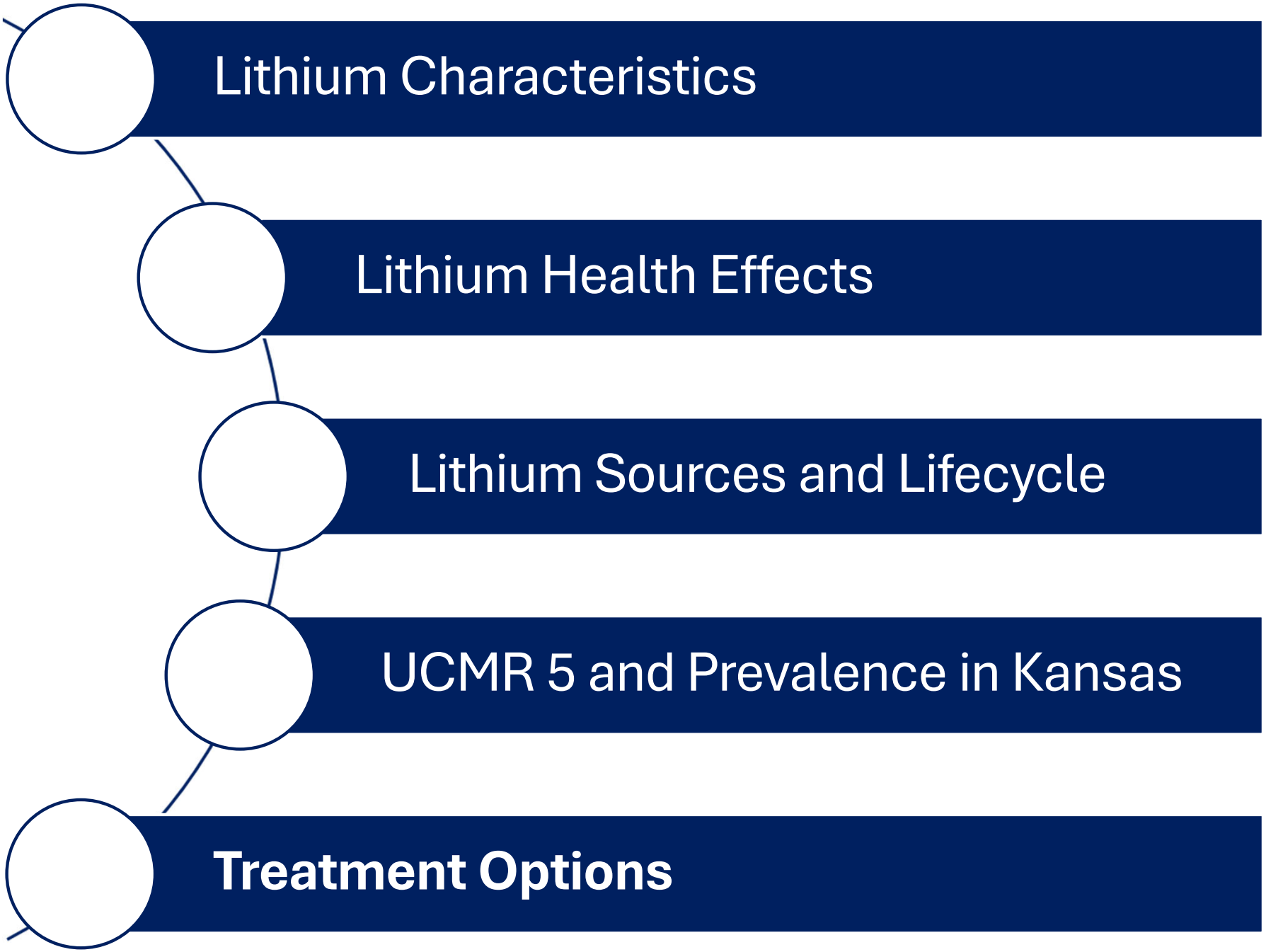
PFAS (ppt)

>20	2.5-5
10-20	1-2.5
5-10	BDL

Lithium (ppb)

>100	20-40
60-100	9-20
40-60	BDL

Outline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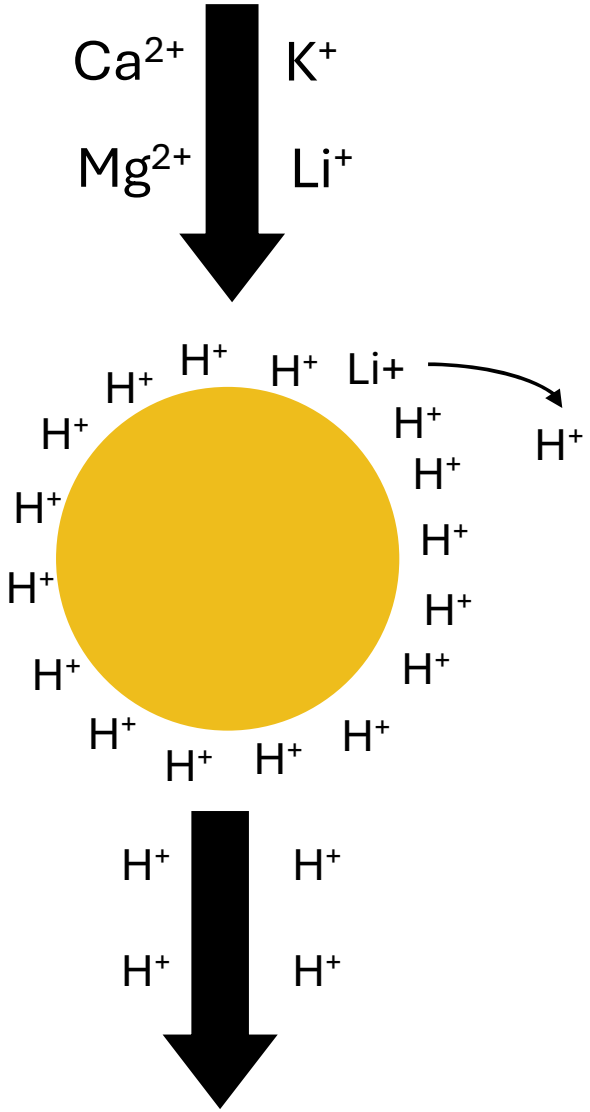
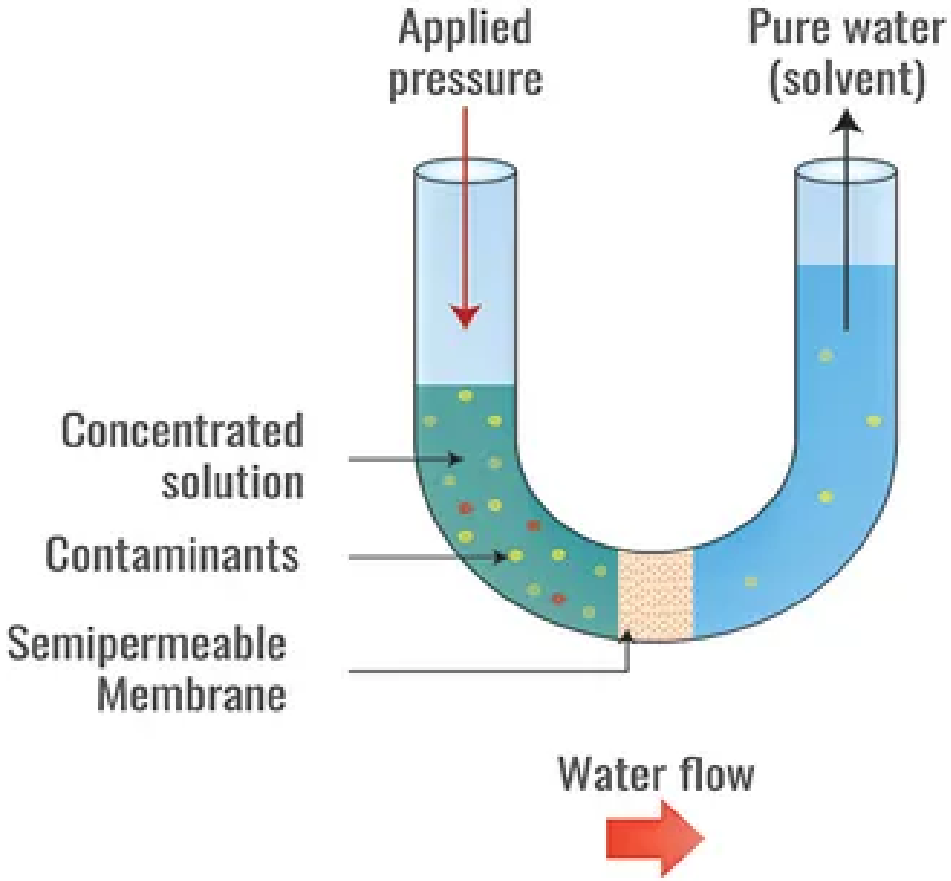
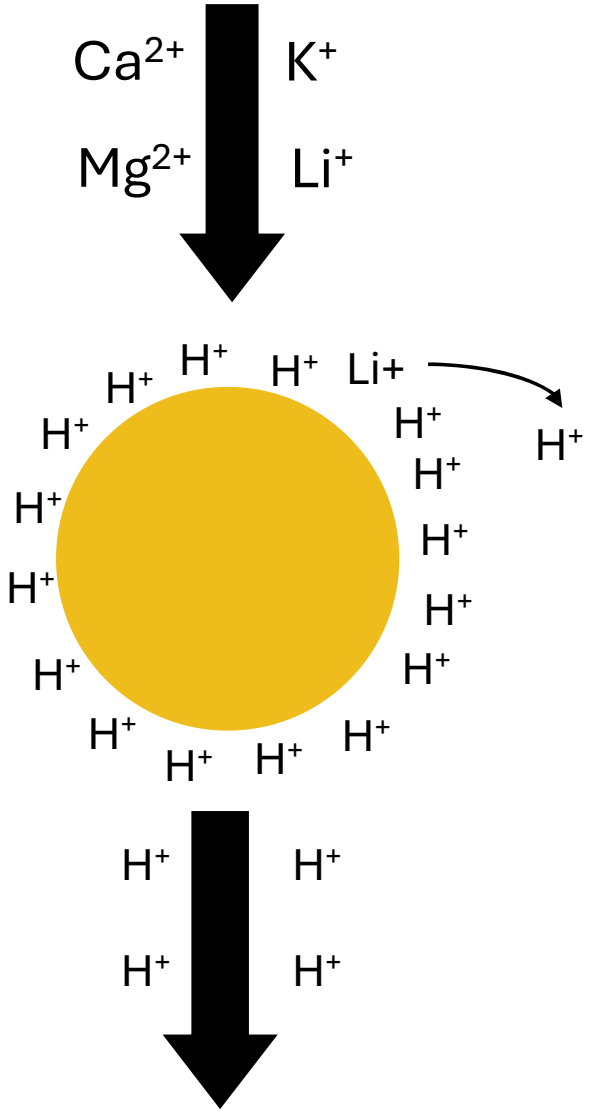
Membrane treatment and ion exchange may be two common treatment options for lithium.





Current cation exchange resins have limited affinity for lithium.

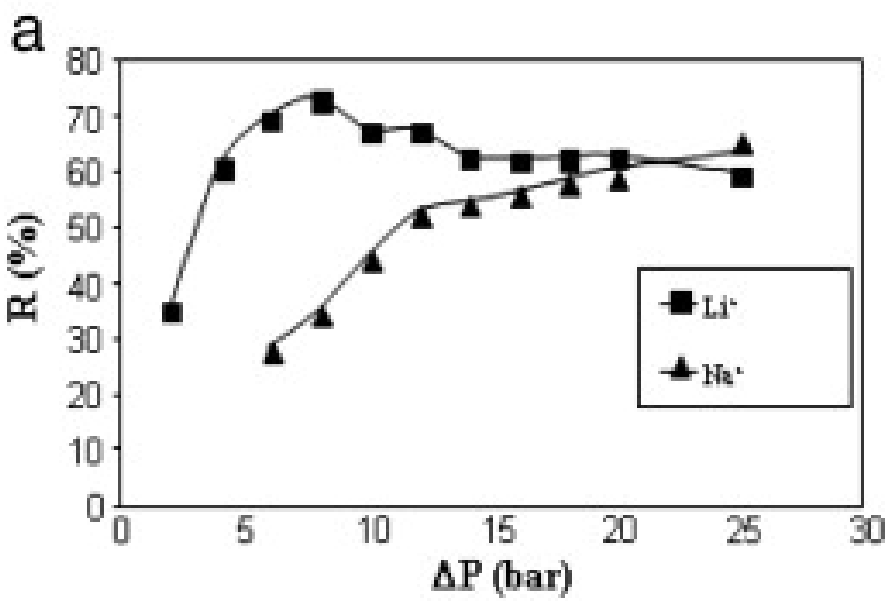


Sulfonated Polystyrene Cation Exchange Resin

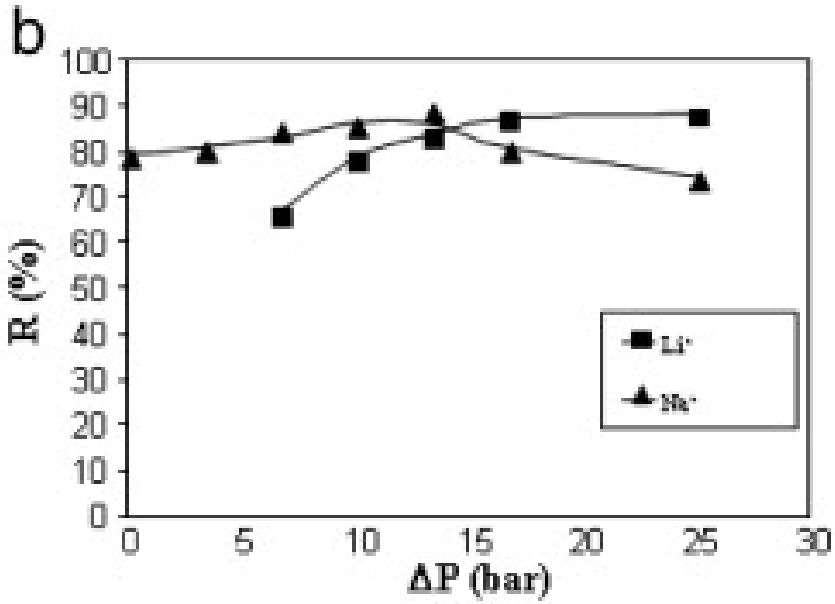
	Percentage of cross-linking of the copolymer			
Cation	4% DVB	8% DVB	10% DVB	16% DVB
Li^+	0.76	0.79	0.77	0.68
H^+	1.00	1.00	1.00	1.00
Na^+	1.20	1.56	1.61	1.62
NH_4^+	1.44	2.01	2.15	2.27
K^+	1.72	2.28	2.54	3.06
Rb^+	1.86	2.49	2.69	3.14
Cs^+	2.02	2.56	2.77	3.17
Ag^+	3.58	6.70	8.15	15.6
Tl^+	5.08	9.76	12.6	19.4
UO_2^{2+}	1.79	1.93	2.00	2.27
Mg^{2+}	2.23	2.59	2.62	2.39
Zn^{2+}	2.37	2.73	2.77	2.57
Co^{2+}	2.45	2.94	2.92	2.59
Cu^{2+}	2.49	3.03	3.15	3.03
Cd^{2+}	2.55	3.06	3.23	3.37
Ni^{2+}	2.61	3.09	3.08	2.76
Ca^{2+}	3.14	4.06	4.42	4.95
Sr^{2+}	3.56	5.13	5.85	6.87
Pb^{2+}	4.97	7.80	8.92	12.2
Ba^{2+}	5.66	9.06	9.42	14.2

Dupont. Ion Exchange Resin Selectivity. 2019

Membrane treatment can reject lithium in salt water, but operational considerations are important.



Nanofiltration 90



Low Pressure Reverse Osmosis

Conclusions

- UCMR 5 is tracking lithium concentrations in drinking water.
- 71.3% of reported concentrations Kansas exceed the Health Based Screening Level.
- If regulations are promulgated, lithium may be difficult to treat using standard drinking water treatment trains.

Acknowledgments

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https://biocatalytics.ku.edu/

Questions?

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