Supplementary materials for:

## Wildfires in the western United States are mobilizing $PM_{2.5}$ -associated nutrients and may be contributing to downwind cyanobacteria blooms

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Species	# smoke days	# total days	% smoke days
Phosphorus	5170 (14305)	31849 (153239)	16.2 (9.3)
Potassium	14298 (14305)	152876(153236)	9.4 (9.3)
Manganese	12074 (14309)	100767 (153321)	12.0 (9.3)
Copper	8236 (14287)	79357 (153024)	10.4 (9.3)
Zinc	13484 (14305)	133208 (153237)	10.1 (9.3)
Aluminum	13754 (14282)	140391 (152745)	9.8 (9.4)
Silicon	14235 (14305)	150943 (153237)	9.4 (9.3)
Calcium	14238 (14281)	151453 (152742)	9.4 (9.3)
Iron	14277 (14305)	151864 (153227)	9.4 (9.3)
Magnesium	10894 (13615)	106190 (145167)	10.3 (9.4)
Nitrate	14260 (14267)	151070 (151553)	9.4 (9.4)
Sodium	11251 (13603)	112674 (145092)	10.0 (9.4)
Ammonium	3473 (3584)	37572 (39819)	9.2 (9.0)

**Table S1.** Number of measurements for smoke days and total days across all monitoring stations and all years combined, and percentage of smoke days compared to total days. The values in parentheses are total measurements and calculations, whereas the values outside the parentheses are the non-zero measurements and calculations.





Species	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	All years
Aluminum	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ammonium	0.905	1.000	0.986	0.924	0.519	0.344	0.168	1.000	0.922	0.991	1.000	0.850	0.244	0.992	1.000	1.000
Calcium	0.000	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Copper	0.207	0.464	0.172	0.501	0.018	0.022	0.737	0.866	0.267	0.160	0.485	0.000	0.000	0.045	0.211	0.246
Iron	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Magnesium	0.001	0.311	0.015	0.000	0.026	0.000	0.000	0.000	0.136	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Manganese	0.000	0.000	0.000	0.000	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Phosphorus	0.198	0.001	0.019	0.210	0.957	0.052	0.000	0.003	0.004	0.003	0.000	0.000	0.000	0.050	0.000	0.000
Potassium	0.000	0.077	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.010	0.000	0.000	0.000	0.000	0.002
Silicon	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sodium	0.023	0.000	0.024	0.008	0.494	0.005	0.003	0.000	0.259	0.000	0.000	0.000	0.023	0.065	0.999	0.000
Nitrate	0.970	1.000	1.000	1.000	0.989	0.987	0.749	1.000	1.000	1.000	1.000	1.000	0.964	1.000	0.410	1.000
Zinc	0.192	0.755	0.962	0.005	0.272	0.253	0.891	1.000	0.009	0.082	0.351	0.000	0.000	0.930	0.000	0.058

**Table S2**. P-values from the permutation test of smoke day concentrations compared to that of non-smoke days for each chemical, for each year. Values in bold are significant at 0.05 or less.

Species	Median % Change	Mean % Change	Max Conc. Change (µg/m³)	Max % Change
Phosphorus	2.7	226.4	0.1	85907.3
Potassium	90.3	137.0	1.8	3414.2
Manganese	57.1	90.0	0.1	2751.9
Copper	18.2	83.6	0.03	4871.9
Zinc	25.2	68.3	0.2	6467.9
Aluminum	44.6	67.9	1.0	1244.0
Silicon	44.7	67.0	2.3	1201.1
Calcium	45.6	64.4	1.2	1334.8
Iron	40.2	59.9	0.8	1264.3
Magnesium	12.2	31.4	0.5	1364.7
Nitrate	1.1	25.9	7.4	1328.6
Sodium	9.6	25.5	2.0	1640.8
Ammonium	-11.4	21.1	4.0	1343.4

**Table S3.** Overview of median and mean percent difference between smoke and non-smoke days, maximum concentration difference, and maximum percent difference across all stations and years.

Species	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Aluminum	72.2	63.7	64.8	36.1	70.1	63.3	73.1	69.6	43.6	67.9	63.0	86.1	67.2	94.6	84.1
Ammonium	-19.1	-14.6	9.4	-20.7	-3.4	0.6	13.2	-11.4	14.4	60.9	-10.7	88.1	61.2	-20.5	226.7
Calcium	71.8	64.0	56.7	36.3	49.5	52.8	64.2	61.2	57.4	64.1	62.8	84.4	58.3	81.9	106.3
Copper	47.3	52.4	77.7	108.1	65.9	19.6	59.0	49.4	54.6	119.0	36.8	145.6	179.7	52.3	197.0
Iron	58.0	53.4	58.3	26.6	66.6	59.4	63.6	50.0	43.6	65.8	60.8	82.7	61.4	66.9	83.9
Magnesium	28.6	-7.6	33.0	19.5	11.9	26.1	38.7	68.8	32.3	58.0	38.0	34.3	15.2	38.6	27.6
Manganese	67.0	67.3	65.9	49.4	76.9	65.9	88.3	66.3	58.0	96.2	88.7	177.5	111.2	106.2	169.9
Phosphorus	-62.4	101.1	-56.1	982.8	28.7	19.5	665.7	176.3	148.1	225.1	218.0	279.7	239.0	123.7	254.4
Potassium	109.5	131.1	80.3	90.9	89.3	87.6	157.8	103.4	105.1	171.7	105.2	216.3	222.3	103.7	292.2
Silicon	60.1	71.1	64.4	31.3	67.0	69.6	69.0	63.1	47.9	63.8	66.2	88.4	59.2	89.2	98.5
Sodium	42.6	69.4	5.2	-5.9	4.9	28.4	25.2	45.6	21.7	81.7	38.9	32.9	1.7	3.4	-6.8
Nitrate	21.8	9.4	16.6	-9.1	-10.1	-1.5	42.7	6.1	20.1	51.6	15.7	47.0	45.5	2.7	138.6
Zinc	24.5	12.8	22.8	29.6	43.9	31.8	66.7	21.1	62.2	75.2	57.6	115.1	190.7	33.8	246.2

**Table S4.** Average percentage change in concentration on smoke days compared to non-smoke days for all species, separated by year.



**Figure S2.** NOAA satellite images of the US West Coast on A) August 19, 2007, B) August 14, 2009, C) September 3, 2012, and D) August 15, 2018, dates corresponding to the Zaca, La Brea, Williams, and Carr fire events, respectively. The orange points are active fires with visible smoke plumes observed.



Figure S3. Burn boundaries of the four case study fires in California.



**Figure S4.** Relative abundance of each species analyzed in Figure 3, with percent of total emissions during case study fires (bottom row) and associated non-fire measurements at the same locations (top row). Species representing  $\geq 4\%$  are labeled.

Chemical species	Difference during Zaca Fire (%)	Difference during La Brea Fire (%)	Difference during Williams Fire (%)	Difference during Carr Fire (%)
Aluminum	25	398	-50	181
Silicon	31	34	-78	136
Calcium	153	1161	430	573
Sodium	12	1070	-100	only present during fire
Potassium	104	7612	4833	2525
Nitrate	84	3278	572	2834
Copper	-74	only present during fire	155	only present during fire
Manganese	only present during fire	300	50	only present during fire
Zinc	only present during fire	2640	746	1800
Magnesium	-33	201	-47	150
Phosphorus	only present during fire	only present during fire	only present during fire	only present during fire
Iron	46	76	-35	256

**Table S5.** Percent differences in  $PM_{2.5}$  chemical species during case study fires compared to the nearest no-fire date at the same location. Negative percentages correspond to concentrations that were higher on no-fire days.

Lake	Surface area (hectares)	Depth (m)	Volume (m <sup>3</sup> )	Latitude, Longitude	Fire event	ΔClcyano
Lake Cachuma	1,255	46	253,000,000	34.580, -119.945	La Brea	5.7
Lake Casitas	445	73	313,000,000	34.381, -119.340	La Brea	0.8
West Valley Reservoir	405	1-3	n/a	41.201, -120.399	Carr	223.8
Red Rock Lake	810	n/a	n/a	41.030, -120.208	Carr	3.9
Honey Lake	22,274	3	150,000,000	40.265, -120.333	Carr	9.5
Eagle Lake	9,710	26	97,000,000	40.651, -120.741	Carr	1.0
Tule Lake	5,260	64	245,700,000	41.896, -121.554	Carr	1.3
Pyramid Lake	510	213	274,000,000	34.656, -118.777	Zaca	35.8
Mystic Lake	810	2	Varies greatly	33.877, -117.078	Zaca	409.8
Perris Reservoir	950	30	162,000,000	33.855, -117.177	Zaca	38.4

**Table S6.** Size parameters, location, and associated fire event for all lakes studied with cyanobacteria analysis.  $\Delta$ CIcyano is the change in cyanobacteria index over the dates listed in Figure S5.



**Figure S5.** Satellite images of cyanobacteria concentrations present in lakes 5 days before and 5-12 days after each corresponding fire event. Pixels are colored based on the cyanobacteria scale (top left) and show increased concentrations of cyanobacteria after fire events.



**Figure S6.** Monthly time series of cyanobacteria index (CIcyano) for all lakes analyzed in Figure 7. Plots are colored based on the circled locations on the maps in Figure 7. The orange shaded region represents smoke coverage over the lakes. Annual CIcyano plots for these lakes are shown in Figure 7.





**Figure S7**. Monthly water quality data for Perris Reservoir, CA, January 2006 through December 2008, including the months around- and corresponding to the Zaca Fire (August 2007). Data points corresponding to the Zaca Fire are shown in orange.





**Figure S8**. Monthly water quality data for Pyramid Lake, CA, January 2006 through December 2008, including the months around and corresponding to the Zaca Fire (August 2007). Data points corresponding to the Zaca Fire are shown in orange.



**Figure S9.**  $\Delta$ CIcyano (the change in cyanobacteria index over the dates listed in Figure S5) for all lakes associated with the case study fires.  $\Delta$ CIcyano was investigated as a function of lake surface area, depth, and volume. No depth data were available for Red Rock Lake. No volume data were available for Red Rock Lake, Mystic Lake, and West Valley Reservoir.