

Supplementary Information

Determination of scaling ions in oilfield produced water by Laser-Induced Breakdown Spectroscopy

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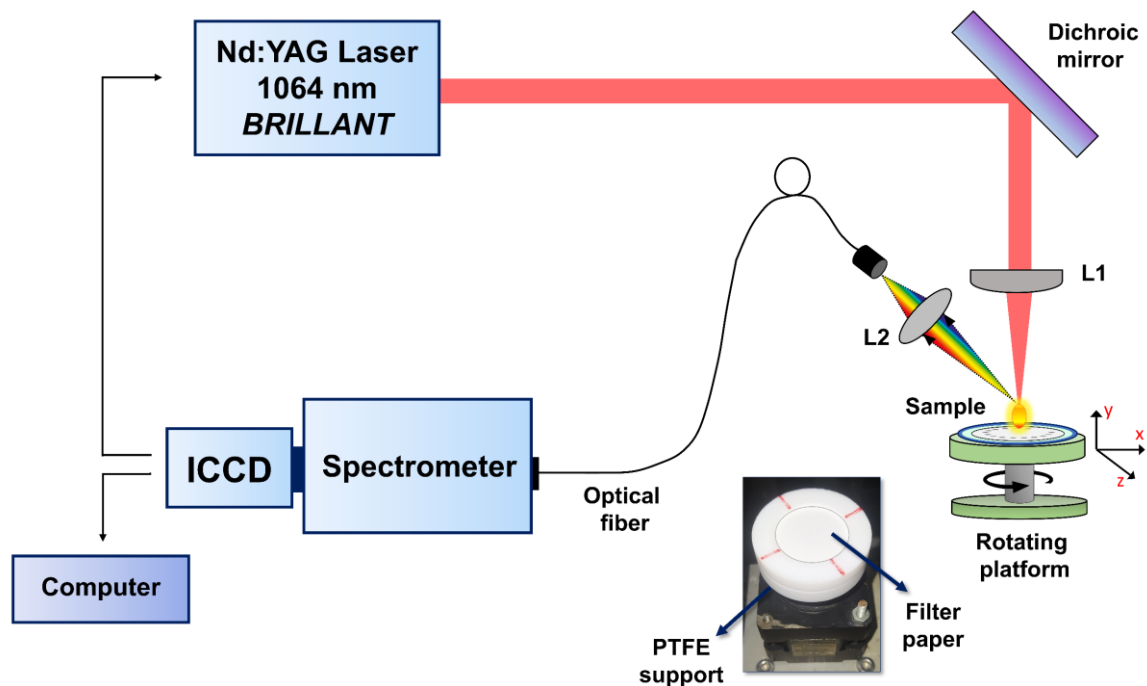


Fig. S1 Schematic diagram of the experimental setup for LIBS measurements.

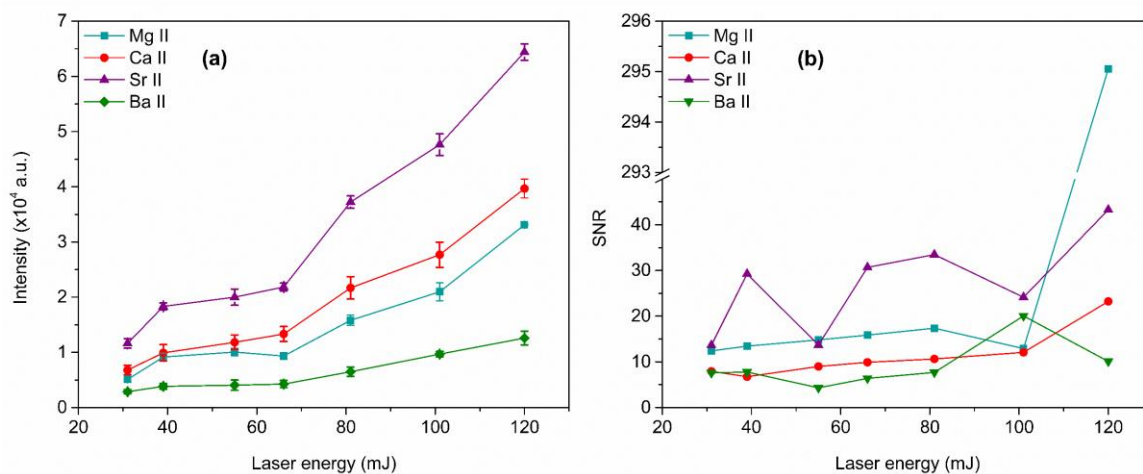


Fig. S2 (a) Emission intensity and (b) SNR as a function of laser energy. Whatman 40 filter paper, gate delay $1 \mu\text{s}$, gate width $1 \mu\text{s}$, sample volume $250 \mu\text{L}$, drying time 60 min. ($n = 3$).

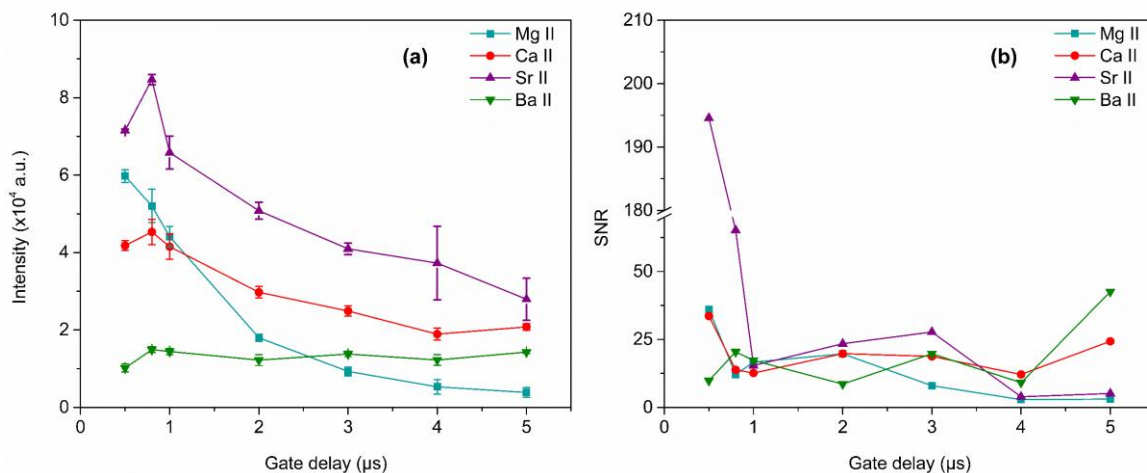


Fig. S3 (a) Emission intensity and (b) SNR as a function of gate delay. Whatman 40 filter paper, laser pulse energy 120 mJ, gate width 1 μs, sample volume 250 μL, drying time 60 min. (n = 3).

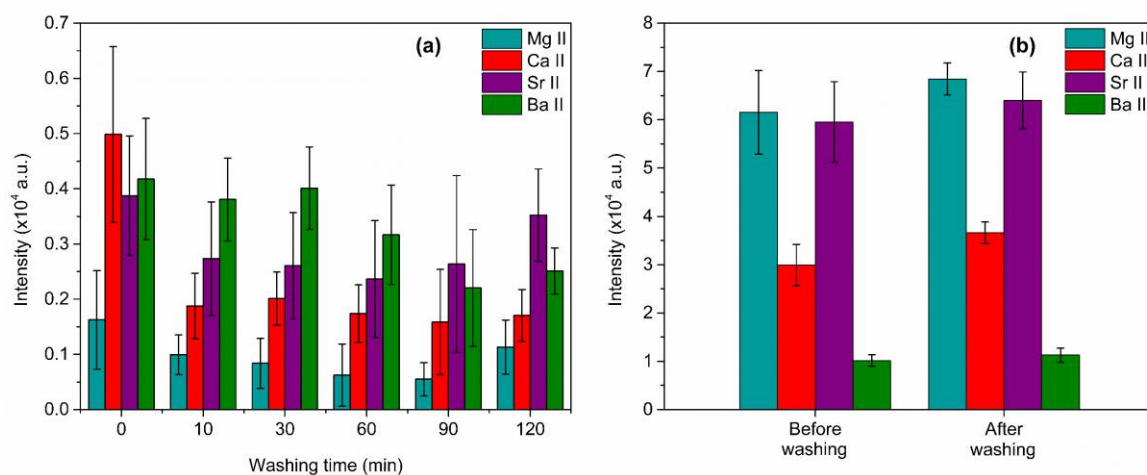


Fig. S4 (a) Emission intensity obtained with the filter paper itself as a function of washing time and (b) emission intensity after sample solution deposition on paper with and without acid washing. Whatman 40 filter paper, laser energy 120 mJ, gate delay 0.8 μs, gate width 1 μs, sample volume 300 μL, drying time 60 min. (n = 3).

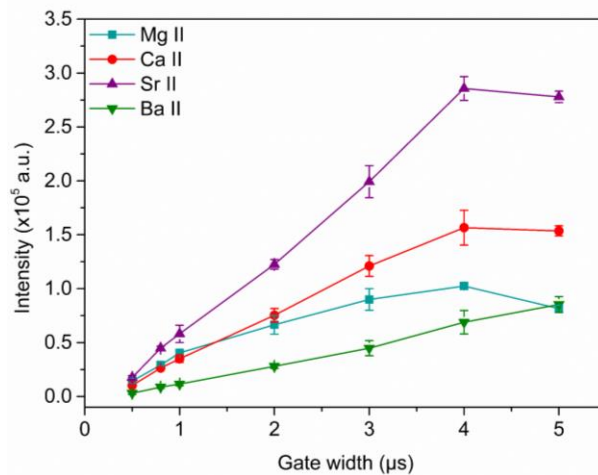


Fig. S5 Variation of the emission intensity as a function of gate width. Whatman 40 filter paper, laser energy 120 mJ, gate delay 0.8 μs, sample volume 250 μL, drying time 60 min. (n = 3).

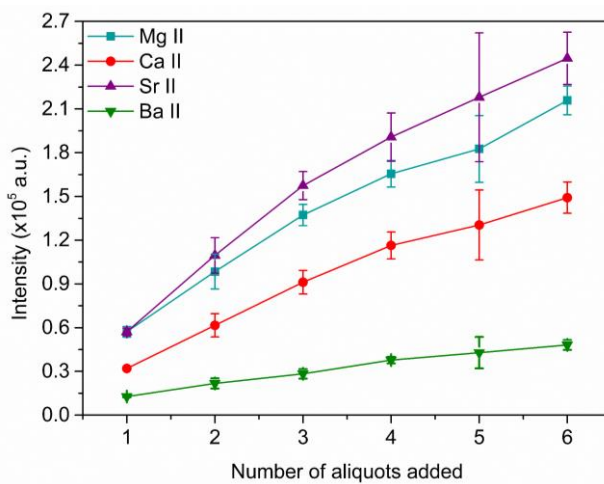


Fig. S6 Variation of the emission intensity as a number of added aliquots of sample (aliquot sample volume of 300 μL). Whatman 40 filter paper, laser energy 120 mJ, gate delay 0.8 μs, gate width 1.0 μs, drying time 60 min. (n = 3).

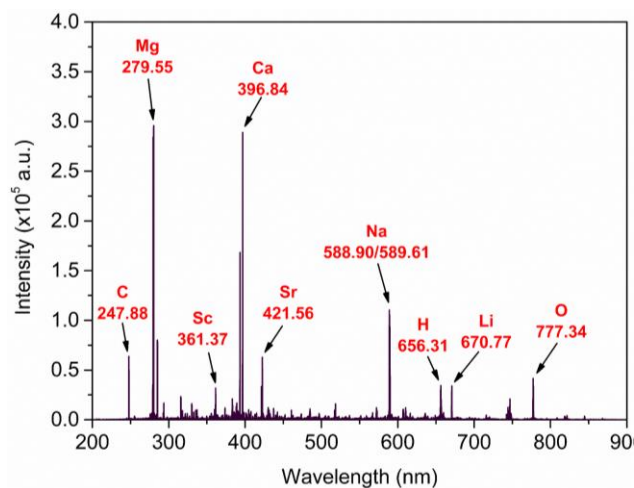


Fig. S7. LIBS spectrum of produced water sample deposited on the filter paper (Whatman 40).

Table S1 Calibration curve parameters obtained after data normalization.

Elements	Li I 670.77			Sc II 361.37			C I 247.88			H I 656.31			O I 777.34		
	Slope	Intercept	R ²	Slope	Intercept	R ²	Slope	Intercept	R ²	Slope	Intercept	R ²	Slope	Intercept	R ²
Mg	0.0691	1.469	0.8544	0.0525	0.928	0.9191	0.0283	0.450	0.9983	0.0433	1.208	0.8990	0.0339	1.182	0.9303
Ca	0.0388	0.443	0.9321	0.0262	0.330	0.9865	0.0150	0.133	0.9990	0.0237	0.405	0.9433	0.0210	0.372	0.9650
Sr	0.0343	0.350	0.9814	0.0241	0.196	0.9908	0.0123	0.110	0.9594	0.0205	0.320	0.9530	0.0184	0.271	0.9970
Ba	0.0108	0.180	0.9886	0.0090	0.037	0.8135	0.0038	0.070	0.7955	0.0062	0.200	0.8794	0.0054	0.169	0.8862

Table S2 Relative error values for the concentration values determined by LIBS without and after normalization with the values determined by ICP OES.

Sample	Mg (WN)	Mg (N)	Ca (WN)	Ca (N)	Sr (WN)	Sr (N)
OPW 1	25%	12%	-5%	2%	-3%	-5%
OPW 2	11%	9%	4%	25%	-4%	-3%
OPW 3	-6%	12%	-6%	12%	17%	-1%
OPW 4	31%	-2%	-1%	19%	18%	1%
SSW 1	142%	7%	88%	11%	18%	2%
SSW 2	314%	55%	243%	48%	200%	25%
SW 1	-4%	3%	-11%	-4%	115%	39%
SW 2	83%	-1%	-15%	-5%	173%	108%
SW 3	53%	1%	81%	11%	785%	144%
SW 4	17%	-5%	57%	5%	205%	14%

OPW = Oilfield produced water, SSW = Synthetic saline water, SW = Seawater. ND = Not detected.

WN: without normalization to C I 247.88 nm, N: with normalization to C I 247.88 nm.