

Figure S1: SEM micrograph of unmodified bentonite sample and the corresponding elemental maps

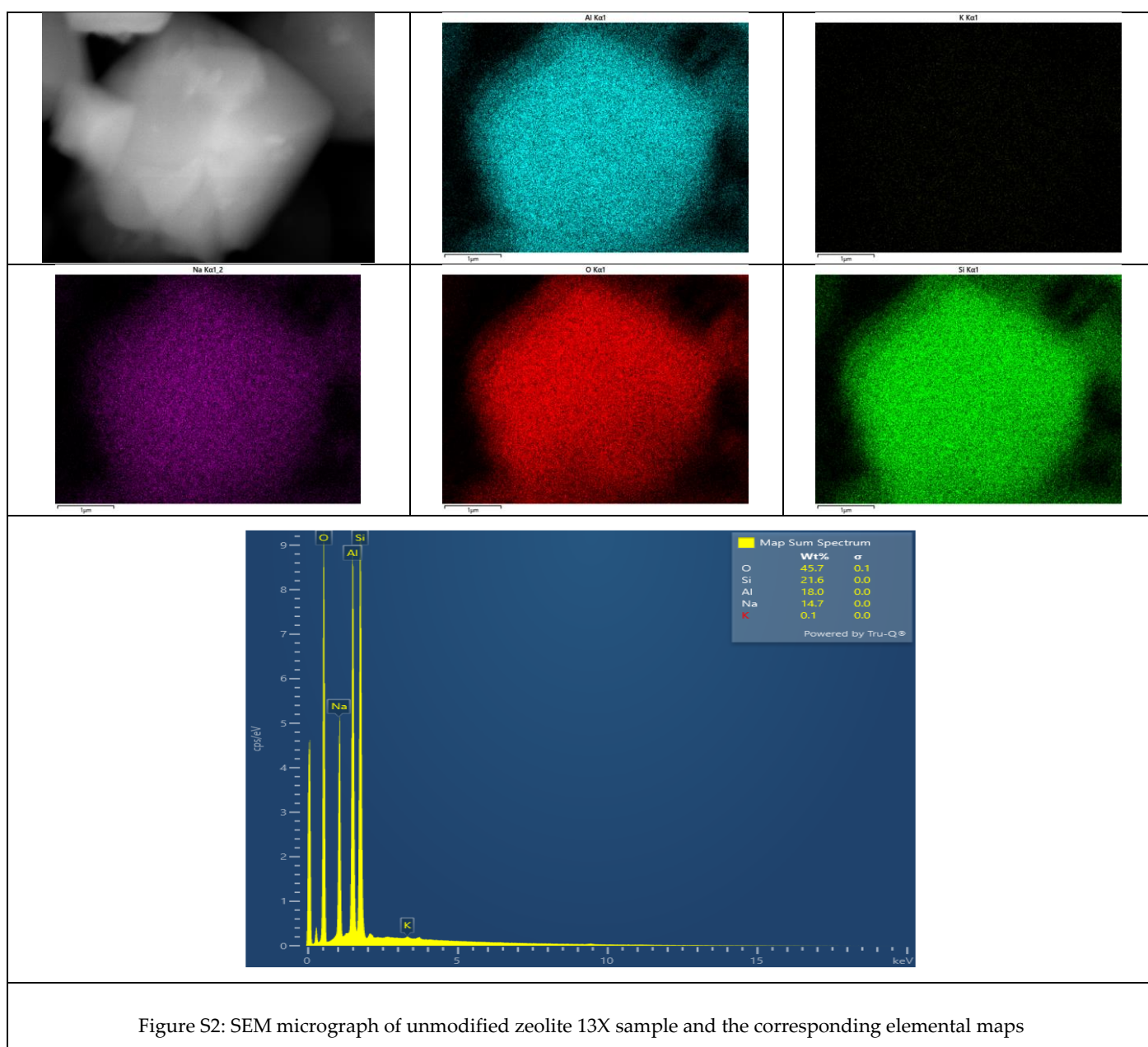


Figure S2: SEM micrograph of unmodified zeolite 13X sample and the corresponding elemental maps

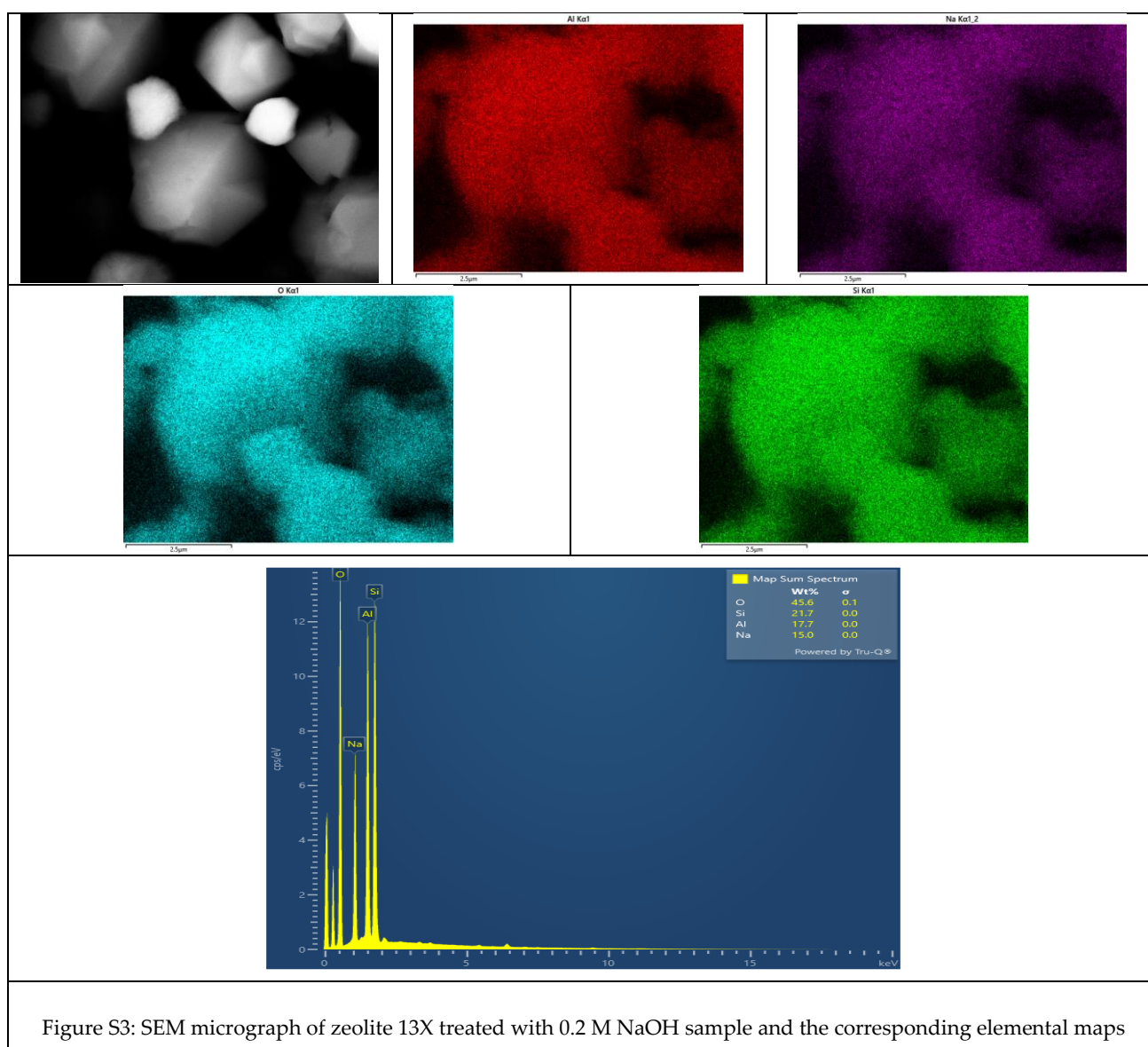


Figure S3: SEM micrograph of zeolite 13X treated with 0.2 M NaOH sample and the corresponding elemental maps

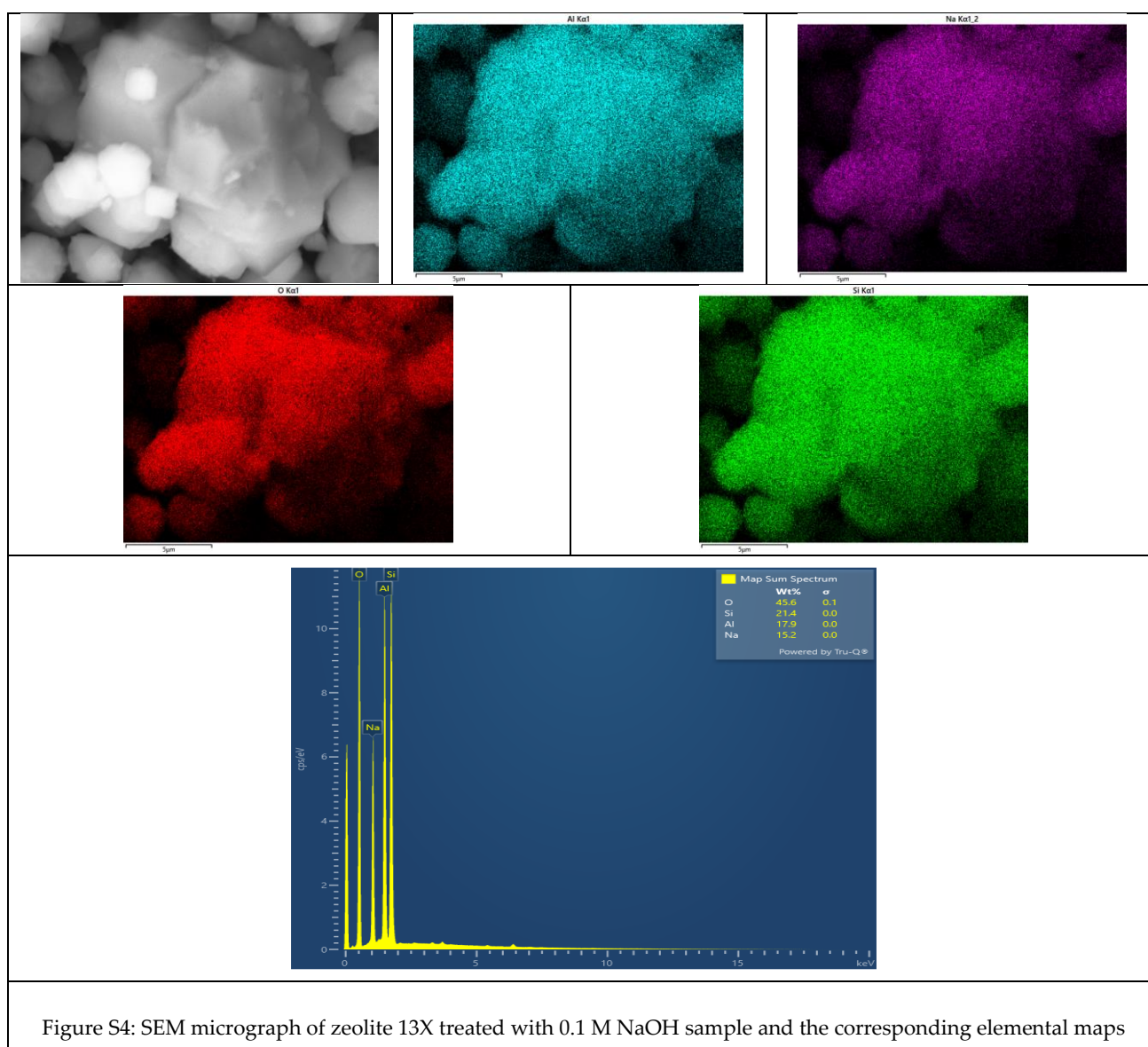
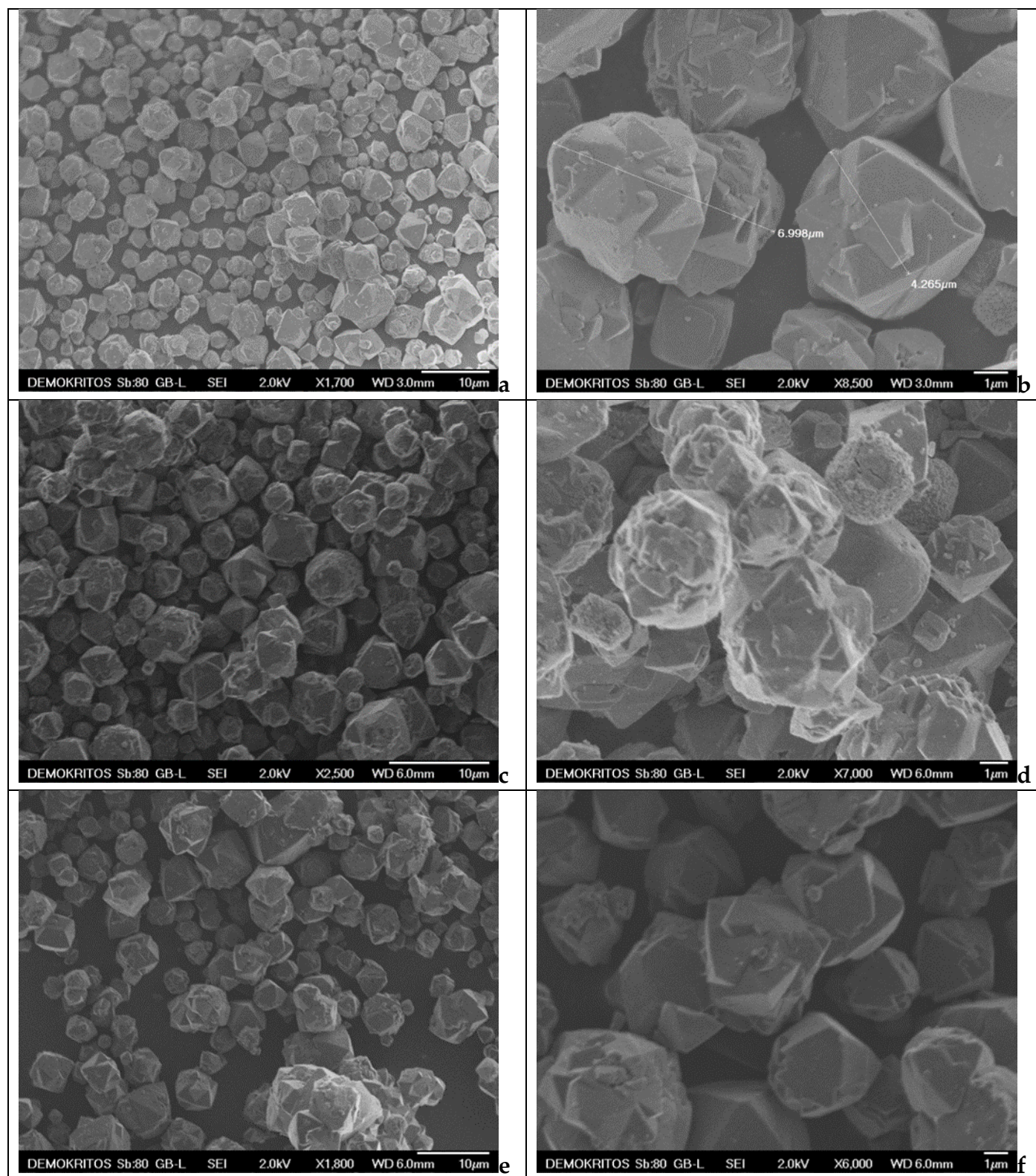


Figure S4: SEM micrograph of zeolite 13X treated with 0.1 M NaOH sample and the corresponding elemental maps





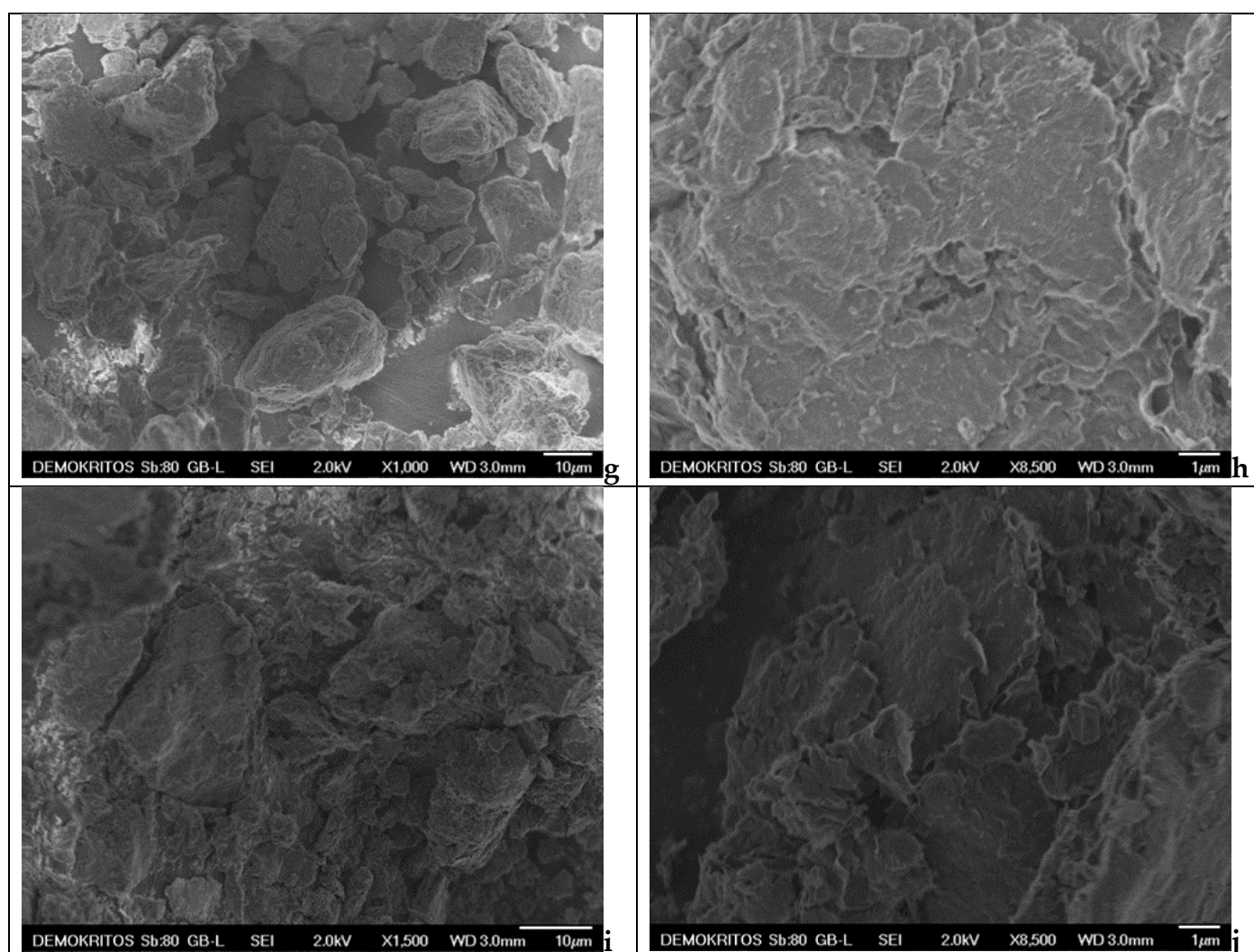


Figure S5. Low and high magnification SEM images of the pristine and NaOH treated samples showing the quite different morphological characteristics of the Bentonite and Zeolite 13X particles. (a, b and g, h) Low and high magnification SEM of the pristine 13X and Bentonite respectively. (c, d) Low and high magnification SEM of the 1M NaOH treated 13X. (e, f and i, j) Low and high magnification SEM of the 0.2M NaOH treated 13 X and Bentonite respectively. Comparison between Figures b, d and f show that the denser NaOH solution starts to erode the surface of the 13X crystal making visible the existence of surface roughness.

**Table S1. Second set: final TAN values of reactors' aqueous phase**

Treatment	TAN (mg N L <sup>-1</sup> ) (value ± SD*)
Be	3653 ± 73.22
Be1	3598 ± 85.81
13X	3582 ± 59.75
13X02	3632 ± 77.85
13X1	3367 ± 42.69
C0	2030 ± 77.36
CNH3	3759 ± 90.15
CSO4	1884 ± 41.95
CNH3-SO4	3551 ± 62.27

\*SD, standard deviation.

**Table S2. First set: daily methane production without the subtraction of the Blank treatment's production (Mean ± SD\*)**

Day	PBe	PBe1	P13X	Treatment P13X02	P13X1	PCNH3	PC0
1	0.56 ± 0.02	1.27 ± 0.07	0.79 ± 0.01	0.94 ± 0.02	0.79 ± 0.01	1.31 ± 0.01	6.46 ± 0.05
2	0.68 ± 0.03	0.86 ± 0.08	0.38 ± 0.01	0.34 ± 0.01	0.35 ± 0.01	0.3 ± 0.03	11.9 ± 0.13
3	2.37 ± 0.05	3.02 ± 0.14	1.54 ± 0.02	1.6 ± 0.01	1.82 ± 0.04	2.06 ± 0.06	19.84 ± 0.14
4	3.27 ± 0.07	4.2 ± 0.18	2.48 ± 0.02	2.55 ± 0.01	2.55 ± 0.04	3.44 ± 0.08	33.56 ± 1.18
5	3.34 ± 0.12	6.41 ± 0.47	2.58 ± 0.1	2.47 ± 0.01	2.91 ± 0.11	3.91 ± 0.09	31.6 ± 1.14
6	5.94 ± 0.15	8.28 ± 0.55	2.67 ± 0.13	3.12 ± 0.04	2.82 ± 0.14	5.26 ± 0.19	31.36 ± 0.67
7	7.22 ± 0.29	9.9 ± 0.42	4.16 ± 0.06	3.87 ± 0.06	3.94 ± 0.09	8.45 ± 0.12	34.08 ± 1.22
8	11.19 ± 0.15	15.01 ± 0.61	6.48 ± 0.17	7.31 ± 0.05	7.23 ± 0.14	11.79 ± 0.13	30.56 ± 2.06
11	41.99 ± 0.69	47.89 ± 0.68	30.47 ± 0.26	30 ± 0.2	26.99 ± 0.26	44.56 ± 0.56	53.15 ± 3.5
13	30.07 ± 0.21	34.81 ± 0.18	23.14 ± 0.5	25.7 ± 0.26	24.91 ± 0.35	34.99 ± 0.32	12.34 ± 0.25
14	15.75 ± 0.21	17.78 ± 0.38	19.06 ± 0.19	17.44 ± 0.16	14.07 ± 0.16	19.78 ± 0.04	7.03 ± 0.3
15	16.68 ± 0.3	19.22 ± 0.21	16.96 ± 0.11	20.55 ± 0.21	14.94 ± 0.11	12.59 ± 0.22	5.87 ± 0.11
18	39.57 ± 2.35	47.13 ± 2.68	53.02 ± 1.32	51.83 ± 1.13	51.53 ± 2.04	38.04 ± 1.06	12.22 ± 0.2
22	43.62 ± 2.49	45.86 ± 0.52	54.44 ± 2.06	52.41 ± 1.23	50.6 ± 2.27	45.73 ± 1.72	2.47 ± 0.09
28	59.76 ± 1.24	46.64 ± 2.39	80.01 ± 1.57	77.16 ± 3.06	77.27 ± 3.15	56.26 ± 2.66	14.26 ± 1.15
35	19.27 ± 0.51	8.53 ± 0.04	16.57 ± 0.46	16.69 ± 0.3	17.36 ± 0.67	8.88 ± 0.54	15.11 ± 0.33

\*SD, Standard Deviation.

**Table S3. Second set: daily methane production without the subtraction of the Blank treatment's production (Mean  $\pm$  SD\*)**

Day	Treatment								
	Be	Be1	13X	13X02	13X1	CNH3-SO4	CNH3	CSO4	C0
1	2.06 $\pm$ 0.04	2.29 $\pm$ 0.01	1.6 $\pm$ 0.01	2.01 $\pm$ 0.1	2.4 $\pm$ 0.02	2.73 $\pm$ 0.06	1.44 $\pm$ 0.11	3.1 $\pm$ 0.04	2.8 $\pm$ 0.08
2	7.45 $\pm$ 0.03	7.24 $\pm$ 0.05	6.3 $\pm$ 0.05	7.22 $\pm$ 0.09	8.2 $\pm$ 0.35	9.75 $\pm$ 0.11	9.41 $\pm$ 0.12	16.7 $\pm$ 0.42	14.69 $\pm$ 0.19
3	11.47 $\pm$ 0.16	12.07 $\pm$ 0.42	10.86 $\pm$ 0.12	9.74 $\pm$ 0.29	12.75 $\pm$ 0.4	13.9 $\pm$ 0.31	14.7 $\pm$ 0.19	26.69 $\pm$ 1.17	25.55 $\pm$ 0.35
4	16.39 $\pm$ 0.19	19.66 $\pm$ 0.28	17.31 $\pm$ 0.13	19.25 $\pm$ 0.15	19.28 $\pm$ 0.23	18.11 $\pm$ 0.08	23.44 $\pm$ 0.64	30.38 $\pm$ 1.07	32 $\pm$ 1.26
5	17.69 $\pm$ 0.17	18.86 $\pm$ 0.37	17.31 $\pm$ 0.15	17.95 $\pm$ 0.05	18.68 $\pm$ 0.18	18.01 $\pm$ 0.02	23.84 $\pm$ 0.21	31.58 $\pm$ 1.21	31.9 $\pm$ 1.3
6	16.63 $\pm$ 0.2	17.48 $\pm$ 0.37	16.84 $\pm$ 0.19	17.94 $\pm$ 0.02	17.86 $\pm$ 0.14	19.16 $\pm$ 0.11	19.82 $\pm$ 0.31	27 $\pm$ 1.58	32.93 $\pm$ 1.26
7	16.77 $\pm$ 0.12	15.79 $\pm$ 0.14	16.21 $\pm$ 0.1	17.29 $\pm$ 0.21	17.9 $\pm$ 0.1	19.76 $\pm$ 0.14	17.21 $\pm$ 0.15	19.05 $\pm$ 0.29	27.58 $\pm$ 1.38
8	16.17 $\pm$ 0.11	15.99 $\pm$ 0.21	16.61 $\pm$ 0.08	17.79 $\pm$ 0.05	16.6 $\pm$ 0.2	17.76 $\pm$ 0.33	17.21 $\pm$ 0.19	15.45 $\pm$ 0.26	27.38 $\pm$ 0.93
9	14.23 $\pm$ 0.17	13.52 $\pm$ 0.33	15.32 $\pm$ 0.3	15.85 $\pm$ 0.31	15.27 $\pm$ 0.5	12.17 $\pm$ 0.33	18.44 $\pm$ 0.32	2.76 $\pm$ 0.26	12.36 $\pm$ 0.32
10	14.33 $\pm$ 0.22	13.22 $\pm$ 0.21	16.52 $\pm$ 0.32	14.65 $\pm$ 0.26	15.87 $\pm$ 0.47	13.07 $\pm$ 0.15	19.04 $\pm$ 0.18	2.76 $\pm$ 0.06	12.06 $\pm$ 0.31
11	8.74 $\pm$ 0.47	7.5 $\pm$ 0.62	9.48 $\pm$ 0.39	9.47 $\pm$ 0.35	9.87 $\pm$ 0.11	8.54 $\pm$ 0.29	13.89 $\pm$ 0.32	1.94 $\pm$ 0.03	8.22 $\pm$ 0.53
12	3.98 $\pm$ 0.07	3.99 $\pm$ 0.16	6.31 $\pm$ 0.22	6.5 $\pm$ 0.21	6.82 $\pm$ 0.38	4.86 $\pm$ 0.12	11.32 $\pm$ 0.18	1.3 $\pm$ 0.07	4.26 $\pm$ 0.14
13	4.08 $\pm$ 0.05	4.89 $\pm$ 0.25	6.61 $\pm$ 0.07	6.2 $\pm$ 0.29	6.52 $\pm$ 0.36	3.86 $\pm$ 0.31	10.72 $\pm$ 0.04	2.1 $\pm$ 0.11	3.46 $\pm$ 0.01
14	4.98 $\pm$ 0.14	4.69 $\pm$ 0.07	6.41 $\pm$ 0.16	6.4 $\pm$ 0.21	6.12 $\pm$ 0.21	3.69 $\pm$ 0.01	11.02 $\pm$ 0.08	1.4 $\pm$ 0.1	3.96 $\pm$ 0.02
15	5.68 $\pm$ 0.15	5.29 $\pm$ 0.22	5.71 $\pm$ 0.18	6.1 $\pm$ 0.24	5.42 $\pm$ 0.32	3.19 $\pm$ 0.12	10.02 $\pm$ 0.15	1.3 $\pm$ 0.02	3.56 $\pm$ 0.03
16	1.74 $\pm$ 0.32	3.29 $\pm$ 0.34	2.19 $\pm$ 0.08	2.1 $\pm$ 0.05	2.29 $\pm$ 0.22	2.79 $\pm$ 0.14	5.68 $\pm$ 0.46	1.59 $\pm$ 0.19	3.57 $\pm$ 0.18
17	1.08 $\pm$ 0.03	1.84 $\pm$ 0.16	1.64 $\pm$ 0.06	1.42 $\pm$ 0.13	2.5 $\pm$ 0.05	2.31 $\pm$ 0.16	2.65 $\pm$ 0.18	0.6 $\pm$ 0.02	3.69 $\pm$ 0.14
18	1.08 $\pm$ 0.08	0.54 $\pm$ 0.1	1.14 $\pm$ 0.04	1.02 $\pm$ 0.03	2.7 $\pm$ 0.07	2.91 $\pm$ 0.19	1.95 $\pm$ 0.2	1 $\pm$ 0.05	3.29 $\pm$ 0.12
19	0.98 $\pm$ 0.01	0.24 $\pm$ 0.16	0.54 $\pm$ 0.09	1.42 $\pm$ 0.12	2.3 $\pm$ 0.11	0.49 $\pm$ 0.1	1.45 $\pm$ 0.03	0.4 $\pm$ 0.06	1.09 $\pm$ 0.01
20	1.58 $\pm$ 0.01	1.44 $\pm$ 0.14	0.54 $\pm$ 0.06	1.22 $\pm$ 0.12	2 $\pm$ 0.03	0.91 $\pm$ 0.01	3.35 $\pm$ 0.06	0.3 $\pm$ 0.04	2.79 $\pm$ 0.01
21	1.18 $\pm$ 0.07	1.94 $\pm$ 0.2	2.04 $\pm$ 0.01	1.12 $\pm$ 0.11	1.5 $\pm$ 0.04	0.41 $\pm$ 0.06	2.25 $\pm$ 0.05	0.5 $\pm$ 0.07	2.09 $\pm$ 0.02
22	0.98 $\pm$ 0.05	0.64 $\pm$ 0.01	1.84 $\pm$ 0.05	0.82 $\pm$ 0.12	1.1 $\pm$ 0.02	0.19 $\pm$ 0.01	2.85 $\pm$ 0.12	0.2 $\pm$ 0.04	0.69 $\pm$ 0.16
23	0.54 $\pm$ 0.01	1.99 $\pm$ 0.16	1.34 $\pm$ 0.03	0.57 $\pm$ 0.07	0.86 $\pm$ 0.05	0.9 $\pm$ 0.13	2.79 $\pm$ 0.1	0.99 $\pm$ 0.07	1.42 $\pm$ 0.02
24	1.03 $\pm$ 0.03	1.03 $\pm$ 0.15	2.01 $\pm$ 0.02	0.93 $\pm$ 0.15	0.38 $\pm$ 0.03	0.59 $\pm$ 0	0.94 $\pm$ 0.15	0.14 $\pm$ 0.02	1.21 $\pm$ 0.04
25	1.43 $\pm$ 0.03	0.33 $\pm$ 0.02	0.51 $\pm$ 0.01	0.73 $\pm$ 0.02	0.48 $\pm$ 0.03	0.79 $\pm$ 0.06	1.34 $\pm$ 0.03	0.46 $\pm$ 0.05	1.09 $\pm$ 0.12
26	1.53 $\pm$ 0.02	1.43 $\pm$ 0.09	1.21 $\pm$ 0.11	1.43 $\pm$ 0.09	0.18 $\pm$ 0.09	0.39 $\pm$ 0.05	1.24 $\pm$ 0.06	0.64 $\pm$ 0.08	0.21 $\pm$ 0.12
27	1.24 $\pm$ 0.08	1.73 $\pm$ 0.11	0.91 $\pm$ 0.12	0.93 $\pm$ 0.06	0.48 $\pm$ 0.03	0.79 $\pm$ 0.02	0.84 $\pm$ 0.18	0.44 $\pm$ 0.06	0.29 $\pm$ 0.05
28	1.83 $\pm$ 0.09	0.73 $\pm$ 0.05	1.91 $\pm$ 0.01	1.33 $\pm$ 0.04	1.08 $\pm$ 0.12	0.39 $\pm$ 0.03	1.84 $\pm$ 0.06	0.84 $\pm$ 0.06	0.21 $\pm$ 0.05
29	0.53 $\pm$ 0.02	1.03 $\pm$ 0.1	1.31 $\pm$ 0.03	0.73 $\pm$ 0.04	0.48 $\pm$ 0.02	0.69 $\pm$ 0.05	1.14 $\pm$ 0.02	0.26 $\pm$ 0.08	0.81 $\pm$ 0.02
30	0.63 $\pm$ 0.08	2.03 $\pm$ 0.04	0.81 $\pm$ 0.06	0.63 $\pm$ 0.02	0.68 $\pm$ 0.09	0.39 $\pm$ 0.1	0.84 $\pm$ 0.12	0.44 $\pm$ 0.03	0.61 $\pm$ 0.14

\*SD, Standard Deviation.